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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE SAN JOSE SCALE AND ITS CONTROL.

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CHARACTER OF INJURY.

The San Jose or Chinese scale[2] infests practically all portions of its host plants that are above ground—the trunk, limbs, and branches—and when abundant it may occur on the leaves and fruit. Injury results from the extraction, by the scale insects, of the juices of the plant. At first this merely checks growth, but as the insects increase in number the speedy killing of the branches and twigs follows, resulting finally in the death of the plants. In addition to the extraction, by the scales, of sap as food, the puncturing of the bark by the slender sucking mouth parts results in a diseased and often pitted condition; the inner bark, or cambium, shows a reddish discoloration, as exposed in cutting with a knife, and the bark itself may crack, in stone fruits exuding drops or masses of gum. A reddening effect is also much in evidence as red rings around the scales on the bark, especially of the apple and pear, and on the fruits of these plants, though not characteristic of any one scale species.

On peach the scales have a tendency to infest to a greater extent the older limbs and branches than the newer growth, such as the wood 1 year old. On apple and pear the terminal twigs are quite generally infested, and many of the young may find their way to the fruit, settling principally in the calyx and stem cavities. Most varieties of fruit trees and plants infested from the nursery perhaps never reach fruiting condition unless treatment be given them. Peach trees will usually be killed in two or three seasons, while pear or apple trees will maintain a feeble existence much longer.

[1] Reprint. Original issue appeared March 30, 1915.

[2] *Aspidiotus perniciosus* Comstock; order Hemiptera, suborder Homoptera, family Coccidæ.

This insect, on account of its great similarity to certain other species of scale insects, may not be positively determined except by specialists. The occurrence of diseased and dying branches showing severe scale infestation furnishes strong presumptive evidence of the presence of this pest, but specimens of infested twigs should be promptly submitted to a qualified person for examination.

The appearance of a three-year-old peach tree, presumably infested from the nursery, is shown in figure 1. The principal limbs have already been killed, although new shoots have developed. A tree in this condition generally may be saved by thoroughly pruning out

FIG. 1.—Appearance of 3-year-old peach tree badly injured by the San Jose scale, the larger branches having been killed. (Author's illustration.)

the dead and badly injured wood and subsequently effecting the control of the scale by spraying. The condition of this tree a year later is shown in figure 2, indicating the recovery following pruning and spraying. Figure 3 illustrates a badly infested six to seven year old peach orchard, the original infestation of which came from an adjacent orchard. Even in the case of peach trees so badly infested as these it is very probable that dehorning and thorough spraying would bring the trees into condition again. It is a matter of judgment, however, whether trees so seriously injured should not be removed.

The character of injury to an apple orchard, in which the trees were infested from outside sources four or five years earlier, is shown

in figure 4. Although many of the limbs and branches are injured or killed, such trees may be saved and brought into vigorous condition by thorough pruning and by insuring the control of the insect in the future.

THE INSECT DESCRIBED.

The mature San Jose scale is small, grayish in color, circular in outline, somewhat convex, and with a nipple-like prominence in the center. The female scale is about 1 millimeter in diameter (about the

FIG. 2.—Appearance of peach tree shown in figure 1, one year later. The dead and injured wood was thoroughly pruned out and the San Jose scale controlled by spraying. (Original.)

size of a pinhead); the male scale is much smaller and elongate. (See figs. 5 and 6.) The insect proper is beneath the so-called scale, this being simply a waxy covering secreted by the soft, helpless, yellow "louse" for its own protection. Where trees and plants are but slightly infested its presence is not readily detected by the casual observer, but in the case of severe infestation (see fig. 6) the bark of the tree

and limbs will present an ash-gray appearance, and on closer examination will be found thoroughly incrusted with the scales, which, when scraped with a knife, will produce a yellowish, oily fluid.

FIG. 3.—Appearance during summer of peach tree 6 to 7 years old badly injured by the San Jose scale. (Original.)

When the scales are abundant on the tree the foliage also will be thoroughly infested, giving it a spotted and diseased appearance readily observable some feet away.

NATURAL HISTORY AND HABITS.

The San Jose scale passes the winter in an immature condition fixed to the bark of the host plant, the small dark-gray or blackish scales being just discernible with the unaided eye. In early spring, with the ascent of the tree's sap, the growth of the scale begins, and early in April, in the latitude of Washington, D. C., the small, two-winged, active males issue from the male scales. After mating with the females the males die. The females continue to grow and in about a month begin the production of living young—minute,

FIG. 4.—Appearance of apple orchard badly infested by the San Jose scale; many of the limbs and branches have been killed. (Author's illustration.)

yellow, oval creatures—which by very close observation may be distinguished without the aid of a hand lens, crawling here and there on the infested plants in an effort to find a suitable place for settlement. The young insect is active for some hours, but soon settles, pushes its slender, threadlike beak into the plant, and begins to feed by sucking out the sap. After this there is no further movement from place to place, and the waxy covering, which often begins to develop before the insect has settled, soon covers it completely.

In about 12 days the insects molt, and from this time on the male and female scales may be readily distinguished. From 8 to 10 days later the males change to pupæ, and in from 24 to 26 days from birth

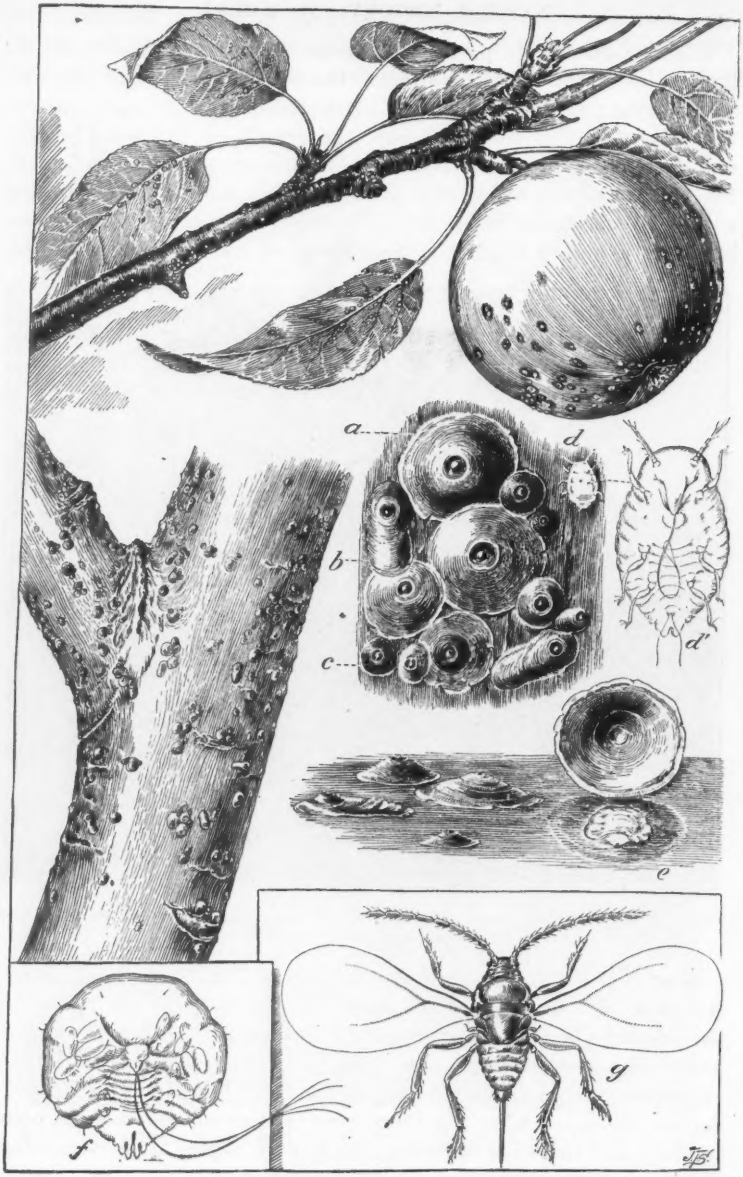

FIG. 5.—San Jose scale: *a*, Adult female scale; *b*, male scale; *c*, young scales; *d*, larva just hatched; *d'*, same, much enlarged; *e*, scale removed, showing body of female beneath; *f*, body of female insect, more enlarged; *g*, adult male of the San Jose scale. (Original.)

the adult males emerge and fecundate the females, which in turn reach maturity and begin the production of young in from 33 to 40 days from birth. An individual female may give birth, on the seasonal average, to about 400 young, and as the life cycle of the female covers but a few weeks there may be several generations a year, the number varying according to latitude. The progeny from one parent during the season have been estimated at 1,608,040,200 females. It is thus easy to understand how the insect can so quickly destroy the plants infested and why prompt remedial measures are so necessary. With the approach of the cool weather of fall, breeding

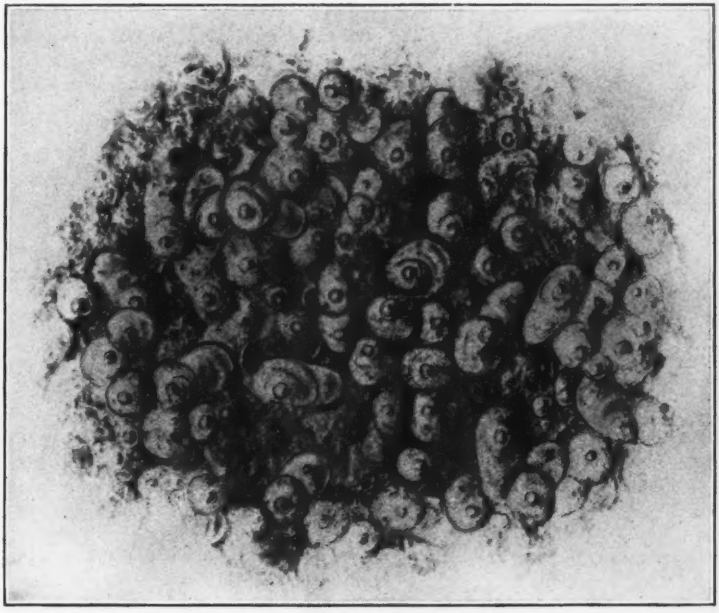

FIG. 6.—Enlarged view of a group of San Jose scales. (Original.)

gradually ceases and the scales in all stages enter hibernation. Most of the older and also most of the younger individuals perish during the winter, the survivors being those about one-third or one-half grown, as stated.

MEANS OF DISTRIBUTION.

The San Jose scale is distributed from one region to another principally on nursery stock, scions, or budding and grafting material. The danger of its dissemination in this way is fully realized, and laws are in force in the majority of States requiring the inspection of nurseries and the destruction of infested stock. Traffic in nursery produce is permissible only under the certificate of an official ento-

mologist or inspector that the stock is free from the scale. In addition to the actual inspection of nurseries, further safeguard is furnished by the practice of most nurserymen (compulsory in some States) of fumigating the plants, before distribution, with hydrocyanic-acid gas.

After the insect once becomes established in a locality its spread is accomplished by various agencies. As explained under the natural history of the insect, it is capable of movement only during a short period after birth. During this crawling stage the insects are able to pass from tree to tree where the limbs are in contact, but it is

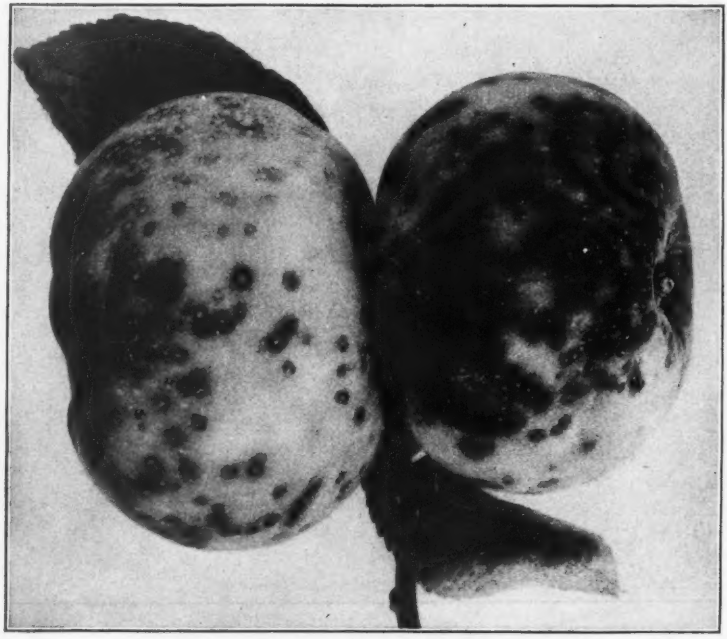

FIG. 7.—Appearance of apples infested with the San Jose scale. (Original.)

by agencies independent of itself that it is principally distributed. Prominent among these factors are birds, which may alight upon infested trees, where the young insects may crawl upon their feet and be subsequently deposited in other trees, sometimes at distances quite remote. It is probable that the young are blown by strong winds from tree to tree; and they are carried by insects, such as grasshoppers, ladybird beetles, ants, etc. The crawling "lice" may be transported considerable distances on the clothing of man, on vehicles, or on horses or other live stock which may be in orchards for any purpose.

The suggestion that the insect may be disseminated by means of scale-infested fruit (see fig. 7) has been frequently made, but it is the consensus of opinion among American entomologists that this danger is negligible.

FOOD PLANTS.

The San Jose scale infests practically all deciduous fruit trees, such as apple, pear, peach, plum, etc., and also many ornamental and shade trees. It is, however, seriously destructive to a much smaller number than that upon which it may actually maintain its existence. The following list of food plants, as compiled by Dr. W. E. Britton,[1] includes those that are commonly or badly infested:

Acacia sp. Lintner, Felt, N. Y.; Alwood, Va.
Akebia sp. Felt, N. Y.
Akebia quinata Decaisne. Alwood, Va.
Shad-bush (*Amelanchier canadensis* Medic.), Juneberry, and other species. Britton, Koehler, Conn.; Alwood, Va.
Citrus trifoliata Linn. Scott, Ga.; Alwood, Va.; Gossard, Fla.
Cornus alba Linn. var. *sibirica* Lodd. Britton, Conn.
Cornus baileyi Coult. & Evans. Gould (in N. Y.).
Cornus sanguinea Linn. Britton, Conn.
Cotoneaster sp.? Britton, Conn.; Lintner, Felt, N. Y.; Card, R. I.
Cotoneaster vulgaris Lindl. Alwood, Va.
Hawthorn (*Cratægus* sp.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.
Cratægus cordata Soland. Koehler, Conn.
English hawthorn (*Cratægus oxyacantha* Linn.). Britton, Koehler, Conn.
Cratægus coccinea Linn. Koehler, Conn.
Cratægus crus-galli Linn. Koehler, Conn.
Common quince (*Cydonia vulgaris* Pers.). Britton, Conn.; Lintner, N. Y.; Alwood, Va.
Japanese or flowering quince (*Cydonia japonica* Pers.). Britton, Koehler, Conn.; Lintner, N. Y.; Alwood, Va.; Johnson, Md.
European purple-leaved beech (*Fagus sylvatica* Linn. var. *purpurea* Ait.). Smith, N. J.
Japanese walnut (*Juglans sieboldiana* Maxim). Britton, Conn.; Alwood, Va.; Sherman, N. C.; Smith, N. J.
Common privet (*Ligustrum vulgare* Linn.). Alwood, Va.
Poplar (*Populus* sp.). Britton, Conn.; Smith, N. J.; Sanderson, Del.; Felt, N. Y.
Carolina poplar (*Populus deltoides* Marsh). Britton, Conn.; Rolfs & Quaintance, Fla.; Alwood, Va.
Lombardy poplar (*Populus nigra* Linn. var. *italica* Du Roi). Britton, Koehler, Conn.; Rolfs & Quaintance, Fla.; Alwood, Va.
Almond (*Prunus amygdalus* Stokes). Lintner, N. Y.; Alwood, Va.
Apricot (*Prunus armeniaca* Linn.). Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.
Sweet cherry (*Prunus avium* Linn.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.; Cockerell, N. Mex.
Prunus pumila Linn. Koehler, Conn.
Sand cherry (*Prunus pumila* var. *besseyi* Waugh). Alwood, Va.
Purple-leaved plum (*Prunus cerasifera* Ehrh. var. *atropurpurea* Dipp. (*P. pissardi*). Britton, Conn.; Felt, N. Y.

[1] Britton, W. E. List of hardy trees, shrubs, and vines commonly or badly infested [by the San Jose scale]. Conn. Agr. Expt. Sta., Rpt. for 1902, pt. II., 2d Rpt. State Entomologist, p. 132-138. 1903.

European plum (*Prunus domestica* Linn.). Britton, Conn.; Alwood, Va.
Wild goose plum (*Prunus hortulana* Bailey). Alwood, Va.
Flowering almond (*Prunus japonica* Thunb.). Britton, Conn.; Felt, N. Y.
Beach plum (*Prunus maritima* Waugh). Koehler, Britton, Conn.
Peach (*Prunus persica* Sieb. & Zucc.). Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Cockerell, N. Mex.
Japanese plum (*Prunus triflora* Roxbg.). Britton, Koehler, Conn.; Alwood, Va.
Prunus serotina Ehrh. Koehler, Conn.
Chokecherry (*Prunus virginiana* Linn.). Koehler, Conn.
Hop tree (*Ptelea trifoliata* Linn.). Fernald, Mass.
Pear (*Pyrus communis* Linn.). Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Cockerell, N. Mex.
Sand pear, including Kieffer (*Pyrus sinensis* Lindl.). Alwood, Va.
Pyrus baccata Linn. Koehler, Conn.
Apple (*Pyrus malus* Linn.). Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Doten, Nev.; Cockerell, N. Mex.
Crab apple (*Pyrus* sp.). Britton, Conn.
Gooseberry (*Ribes oxyacanthoides* Linn.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Troop, Ind.
Missouri or flowering currant (*Ribes aureum* Pursh.). Lintner, N.Y.
Currant (*Ribes rubrum* Linn.). Britton, Conn.; Lintner, Felt, N. Y.
Black currant (*Ribes nigrum* Linn.). Alwood, Va.
Rosa sp. Britton, Conn.; Lintner, N. Y.; Alwood, Va.; Cockerell, N. Mex.; Burgess, Ohio; Troop, Ind.; Gould, Md.; Scott, Ga.
Rosa carolina Linn. Koehler, Conn.
Rosa lucida Ehrh. Koehler, Conn.
Rosa virginiana Mill. Koehler, Conn.
Rosa rugosa Thunb. Britton, Koehler, Conn.
Willow (*Salix* sp.). Britton, Conn.; Felt, N. Y.; Sanderson, Del.
Salix lucida Muhl. Koehler, Conn.
Laurel-leaved willow (*Salix pentandra* Linn.). Lintner, N. Y.; Alwood, Va.
Salix vitellina Linn. Koehler, Conn.
Weeping willow (*Salix babylonica* Linn.). Lintner, N. Y.; Alwood, Va.
Salix humilis Marsh. Koehler, Conn.
Salix incana Schrank. Koehler, Conn.
Mountain ash (*Sorbus* sp.). Felt, N. Y.; Hunter, Kans.
American mountain ash (*Sorbus americana* Marsh). Britton, Koehler, Conn.; Alwood, Va.
European mountain ash (*Sorbus aucuparia* Linn.). Britton, Koehler, Conn.
Black chokeberry (*Sorbus melanocarpa* C. Koch [*Aronia nigra* Koehne]). Koehler, Conn.
Snowberry (*Symphoricarpos racemosus* Michx.). Felt, N. Y.; Smith, N. J.
Common lilac (*Syringa vulgaris* Linn.). Burgess, Ohio; commissioner of agriculture, N. Y.; Troop, Ind.; Alwood, Va.
Persian lilac (*Syringa persica* Linn.). Britton, Conn.
Basswood, linden (*Tilia* sp.). Britton, Conn.; Lintner, commissioner of agriculture, N. Y.
American linden or basswood (*Tilia americana* Linn.). Britton, Conn.; Alwood, Va.
Osage orange (*Toxylon pomiferum* Raf.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.
Elm (*Ulmus* sp.). Lintner, N. Y.; Webster, Ohio; Troop, Ind.
American elm (*Ulmus americana* Linn.). Britton, Koehler, Conn.; Alwood, Va.
English or European elm (*Ulmus campestris* Smith). Britton, Conn.; Felt, N. Y.; Smith, N. J.

This list might be materially extended by recording those plants upon which the insect has at various times been taken but to which it is not especially injurious. The fears earlier expressed that the scale would eventually seriously infest our native forest growth have not been borne out, and in effect it requires treatment only on fruit trees, bush fruits, and ornamental trees and plants.

NATURAL ENEMIES.

The San Jose scale is subject to attack by numerous predaceous and parasitic enemies, which render important service in its control. Practically, however, the combined influence of these several agen-

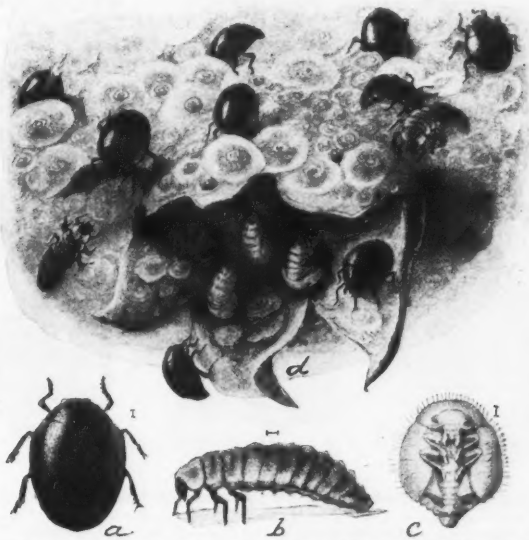

FIG. 8.—The pitiful ladybird: *a*, Beetle; *b*, larva; *c*, pupa; *d*, blossom end of pear, showing scales with larvæ of ladybird feeding on them, and pupæ of ladybird attached within the calyx. All greatly enlarged. (From Howard and Marlatt.)

cies is not sufficient to make up for the enormous reproductive capacity of this insect. To preserve the plants from destruction, its control must be accomplished by artificial means, such as the use of sprays.

Among the more common predaceous insects which are observed feeding on the scale is the so-called pitiful ladybird,[1] illustrated in figure 8. This very small, convex, black beetle may generally be found by any observant person on scale-infested trees.

Another species that feeds very commonly on this and other scale insects is the twice-stabbed ladybird.[2] This is a very near relative

[1] (*Pentilia*) *Microweisea misella* Lec.

[2] *Chilocorus bivulnerus* Muls.

and almost identical in appearance with the Asiatic ladybird[1] (fig. 9), which was introduced into this country from China through the activities of Mr. C. L. Marlatt, of the Bureau of Entomology, in the hope that its introduction would result in the control of this insect. The Asiatic ladybird, however, unfortunately proved to be subject to certain native parasites, while the necessity of spraying for the scale destroyed its food supply to such an extent that it was unable to maintain its existence.

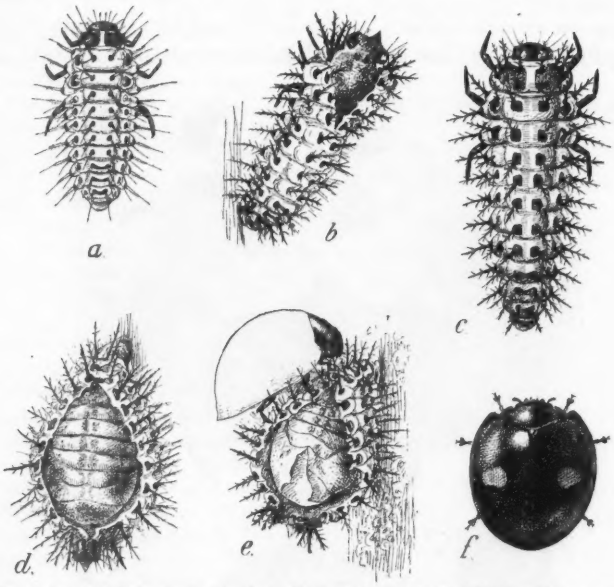

FIG. 9.—The Asiatic ladybird, almost identical with the twice-stabbed ladybird, predatory on the San Jose scale: *a*, Second-stage larva; *b*, cast skin of same; *c*, full-grown larva; *d*, method of pupation, the pupa being retained in the split larval skin; *e*, newly emerged adult not yet colored; *f*, fully colored and perfect adult. All enlarged to the same scale. (From Marlatt.)

In addition to the enemies just mentioned, there are certain very minute, four-winged flies (see fig. 10) belonging to the parasitic Hymenoptera, which are true parasites of scale insects. These place their eggs beneath the scales, some species attacking the scale insect while others attack the eggs. The resulting grubs kill the insect or devour the eggs. When the parasite has become fully developed it escapes through a small, round hole which it gnaws through the scale. Parasitism of the San Jose scale by these insects can be determined by inclosing in a glass vial a badly infested twig, for in the course of a few days the minute flies, if present, will begin to emerge. Dr. L. O. Howard and Mr. R. A. Cushman have prepared the

[1] *Chilocorus similis* Rossi.

following list of parasites which have been reared from the San Jose scale: *Aphelinus fuscipennis* How., *Aphelinus mytilaspidis* LeB., *Aphelinus diaspidis* How., *Aspidiotiphagus citrinus* (Craw) (fig. 10), *Anaphes gracilis* How., *Physcus varicornis* How., *Prospaltella aurantii* How., *Prospaltella perniciosi* Tower, *Prospaltella fasciativentris* Gir., *Ablerus clisiocampae* Ashm., *Rhopoideus citrinus* How., *Perissopterus pulchellus* How., *Arrhenophagus chionaspidis* Auriv., *Anagrus spiritus* Gir., *Signiphora nigrita* Ashm., *Coccophagus immaculatus* How., *Coccophagus lecanii* Fitch, and *Microterys* sp.

While the benefits arising from the work of these parasites are undoubtedly great, the percentage of control of the scale thus accomplished varies greatly with the locality and the time of year, and from season to season. The highest percentage of parasitism thus far observed, and far in excess of the average, is 90. The remaining

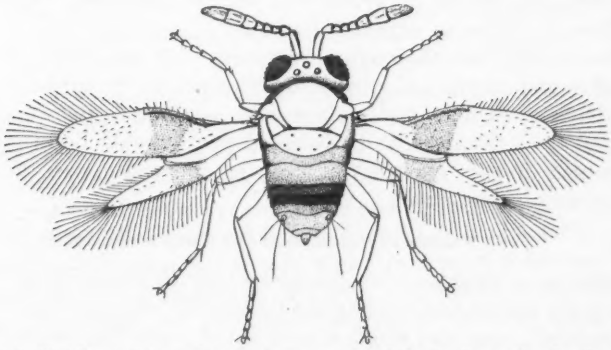

FIG. 10.—*Aspidiotiphagus citrinus*, a hymenopterous parasite of the San Jose scale. Greatly enlarged. (From Howard.)

10 per cent of healthy scales would suffice for reproduction of the scale in injurious numbers. It is, therefore, readily seen that, even with this high percentage of parasitism, the control of the scale by these agencies can not be depended upon.

Considerable attention has been given to the subject of fungous diseases of the San Jose scale, and numerous attempts conducted in a thoroughly scientific manner, notably by Prof. P. H. Rolfs, director of the Florida Agricultural Experiment Station, have been made to utilize one of these parasitic plants in the control of the insect. The fungus in question, *Sphaerostilbe coccophila*, is cosmopolitan in its distribution, infesting many armored scale insects,[1] and in Florida and the territory adjacent to the Gulf it is quite generally present on scales in orchards and on shade and forest trees. Its abundance and effectiveness, however, depend upon certain weather conditions, and therefore vary considerably.

[1] Subfamily Diaspinæ.

CONTROL MEASURES.

As has been already stated, the San Jose scale, in the absence of proper treatment, will quickly bring about the death of many plants of economic importance. Its discovery, therefore, whether in orchards or on prized fruit trees and other plants in the yard, should call for prompt steps toward its control. It has been amply demonstrated that the scale may be very successfully controlled, and practically its presence merely requires one thorough treatment during the dormant period each year. On account of the general distribution of the pest extermination measures are, in most cases, out of the question.

Complaint sometimes comes from orchardists who have the scale to contend with that the control of the insect is neglected by their neighbors, and they believe this neglect adds materially to their own work. Undoubtedly the scale will spread from orchard to orchard, but thorough annual sprayings will prevent important injury irrespective of neglect in adjacent orchards.

Where plants are thoroughly incrusted, with consequent death of branches and stunting of growth, it will generally be advisable to dig out the trees at once and replace with new ones. Before spraying infested trees the dead and weakened wood should be pruned out, which will simplify the work of spraying and will hasten the formation of new, sound wood.

THE WASHES IN USE AGAINST THE SAN JOSE SCALE.

There are several scale washes which may be employed in the control of the insect, and the one should be selected which can be most conveniently used and which is economical under the circumstances. Thus, for spraying on a large scale, the orchardists could properly afford expenditures for the construction of cooking outfits for lime-sulphur wash which would not be justified where only a few trees were involved. For a few plants it would be better to use some one of the prepared washes put up by manufacturers. In fact, many large orchardists prefer to use sprays of this class in preference to making the washes at home. The possibility of injury to the trees from the sprays must also be borne in mind. All treatments, if possible, should be made during the dormant period (that is to say, in late fall or early spring, or even during the winter in mild climates), since at this time washes may be applied at much greater strengths than when the trees are in foliage. The aim is to use the wash about as strong as the tree will stand, thereby securing the maximum killing effect upon the insects. Used in this way the washes of the petroleum or kerosene series are most likely to cause injury to the fruit buds and tender twigs, and the lime-sulphur washes least likely to do so. Fish-oil soap sprays as recommended for dormant trees are comparatively safe, though reports are at hand of injury to

fruit buds, especially from fall applications. Stone fruits, such as peach, plum, etc., are more susceptible to injury from sprays than apple and pear, and on the former the lime-sulphur sprays should always be used. Petroleum and miscible oils are more frequently used on apple and pear, and owing to their spreading and penetrating qualities are perhaps more effective in destroying the scales on the terminal twigs, which are infested to a greater extent in the case of these fruits. The several sprays in use may be considered under the following headings: (1) Lime-sulphur wash series; (2) petroleum-oil series (including miscible oils), and (3) soap washes.

LIME-SULPHUR WASH SERIES.

For several years the cooked lime-sulphur wash was the main reliance in the control of the scale. It is made according to the following formula:

Stone lime	pounds..	20
Sulphur (flour or flowers)	do....	15
Water to make	gallons..	50

Heat in a cooking barrel or vessel about one-third of the total quantity of water required. When the water is hot add all the lime and at once add all the sulphur, which previously should have been made into a thick paste with water. After the lime has slaked, about another third of the water should be added, preferably hot, and the cooking should be continued for one hour, when the final dilution may be made, using either hot or cold water, as is most convenient. The boiling due to the slaking of the lime thoroughly mixes the ingredients at the start, but subsequent stirring is necessary if the wash is cooked by direct heat in kettles. If cooked by steam, no stirring will be necessary. After the wash has been prepared it must be well strained as it is being run into the spray tank. It may be cooked in large kettles, or preferably by steam in barrels or tanks. This wash should be applied promptly after preparation, since, as made by this formula, there is crystallization of the sulphur and hardening of the sediment upon cooling. Probably comparatively few fruit growers at the present time prepare the wash according to this old method, but employ the commercial or homemade concentrate.

COMMERCIAL LIME-SULPHUR CONCENTRATES.

The inconvenience experienced in preparing the lime-sulphur wash according to the foregoing formula by cooking with steam or in open kettles at home has been one of the principal objections to this spray. Manufacturers have, therefore, put on the market concentrated solutions of lime-sulphur which have only to be diluted with water for use. These commercial washes, if used at proper strength, have proved to be quite as satisfactory in controlling the scale as

the old-formula lime-sulphur wash, and, although somewhat more expensive, have been adopted by many of the commercial orchardists in preference to the "20–15–50" formula. They are especially useful for the smaller orchardists whose interests do not warrant the construction of a cooking plant.

Homemade Lime-Sulphur Concentrates.

The question of the preparation at home of concentrated lime-sulphur solutions which will not crystallize upon cooling, thus duplicating the commercial product, has been investigated by the Bureau of Entomology, as well as by numerous experiment station entomologists, notably by Profs. Stewart, Cordley, Parrott, and others. It has been demonstrated that it is practicable for orchardists to prepare concentrated stock solutions of lime-sulphur wash for immediate or later use, and many orchardists employ this plan. The necessary details for the preparation at home of lime-sulphur concentrates are given below.

Directions for Preparation of Lime-Sulphur Concentrates.

The so-called 50–100–50 formula, composed of 50 pounds of lime, 100 pounds of sulphur, and water to make 50 gallons, has been generally recommended for the preparation of a homemade concentrated lime-sulphur solution. Some advise the use of five or six pounds of sulphur more than above stated in order to have a slight excess of this ingredient over the lime. The method of preparation is to boil together in the necessary water the respective ingredients for from 50 minutes to an hour. A good grade of fresh stone lime containing not less than 90 per cent of calcium oxid is necessary for the best results. Hydrated lime is sometimes used, but it is necessary to use a good grade and at least 20 per cent more of this form of lime is required, as it contains a high percentage of moisture.

Place enough water in the cooking vessel to finish with 50 gallons of the solution; bring the water to the boiling point, then put in the lime and immediately add the sulphur. If the plant is equipped with an agitator, this should be started with the addition of lime and sulphur. If there is no mechanical agitator, the mixture must be stirred vigorously by hand until the lime is slaked, and necessary agitation must be given throughout the time of cooking. If the solution is to be put in barrels without filtering, it should be drawn off as soon as the period of cooking is completed, and allowed to run through a 30-mesh strainer into the barrels. The agitation should be continued while the solution is being drawn off so that there will be an equal distribution of the sludge in the different storage receptacles.

The density of the concentrate, made according to the formula 50–100–50, has varied, in the experience of the Bureau of Entomology, from 24 to 28 degrees Baumé, and theoretically should be 26° by this scale. It is quite desirable for economy in storage space to prepare as highly concentrated a solution as possible. This can be done with reduced quantity of water after the following formula, which will give a solution of a density of from 32 to 34 degrees Baumé.

Fresh stone lime	pounds..	80
Commercial ground sulphur	do....	160
Water to make, of the finished product	gallons..	50

While this formula gives about 50 per cent in volume of sludge, after allowing the solution to settle for 24 hours, there is only about 5 to 10 per cent in volume of insoluble material, which would be removed in the straining process. This volume of sludge will not be objectionable in spraying, provided the insoluble material has been properly strained out.

HANDLING AND STORAGE.

It is very desirable in most cases to make up a supply of lime-sulphur solution during the winter or early spring, before spraying operations begin. It is quite feasible to do this, as the solution can be kept a year or more when properly stored. It should be placed in barrels or other tight receptacles and carefully stoppered so as to exclude the air as much as possible, as this slowly causes the wash to deteriorate. The barrels or other container should be completely filled, so that there will be little or no air space above the surface of the liquid. In the preparation of the lime-sulphur concentrate at home the disposition of the sludge is a question of practical importance. Commercial manufacturing plants are usually supplied with a filter press by means of which the wash, as it comes from the cooking tank, is filtered, freeing it from sludge and sediment. There seems, however, to be no objection to storing the solution without removal of sludge, though the sediment should be strained out as already stated.

Lime-sulphur solution should not be allowed to freeze, as this greatly reduces its strength. It does not freeze easily, however, and the temperature at which it freezes varies with its strength; the stronger the solution, the less easily it is frozen. It will stand a considerably lower temperature without freezing than will water.

COOKING PLANTS.

Lime-sulphur concentrate may be made by orchardists with very simple appliances, such as a large kettle suspended on a pole or raised from the ground on loose stones. One or two such kettles embedded in masonry would be more convenient, however, and would permit the

development of necessary facilities for water supply. (See fig. 11.) Ordinary feed cookers or jacketed kettles are also very satisfactory. Small steam boilers of a few horsepower capacity serve especially well for a medium-sized orchard.

Where the amount of concentrate to be made is considerable, as for a large orchard or for the fruit growers of a neighborhood, it will pay to construct a more elaborate cooking plant. A convenient outfit is shown in figure 12. In the construction of these plants careful attention should be given to the arrangement of the cooking vessel, the water supply, and the arrangement for drawing off the cooked wash. A

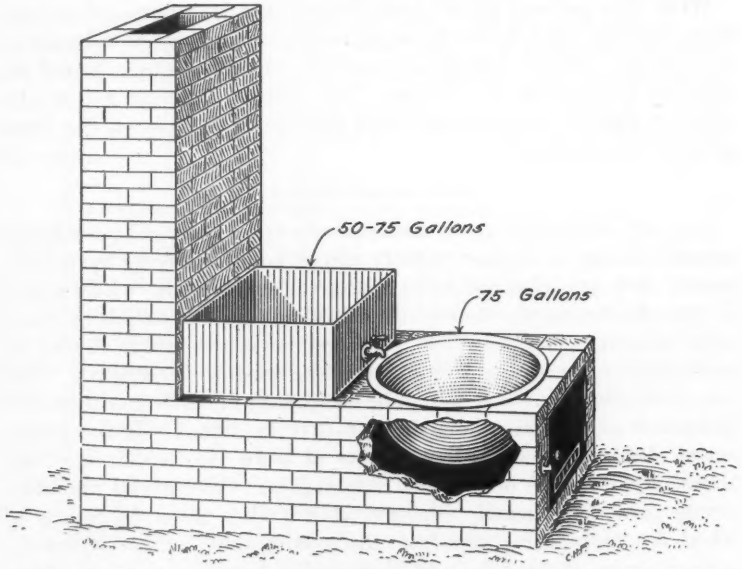

FIG. 11.—Lime-sulphur cooking outfit for preparing wash for small to medium sized orchards. Prepared by E. W. Scott. (Original.)

12-horsepower boiler will furnish sufficient steam for a cooker of 300 gallons capacity. However, if a steam engine is to be used for running the agitator, a somewhat larger boiler will be necessary. The cooking vessel may be either of wood or iron, though an iron vessel is usually more satisfactory owing to the difficulty in preventing leakage of wooden vessels. If the cooking vessel is not provided with a pump it should be so elevated that the cooked concentrate may be drawn off by gravity into a settling tank or storage vessels. Vinegar barrels, or barrels which have been used for acids, should not be employed in storing the solution, as the acid breaks down the concentrate. Kerosene oil barrels and whisky barrels are used to a large extent.

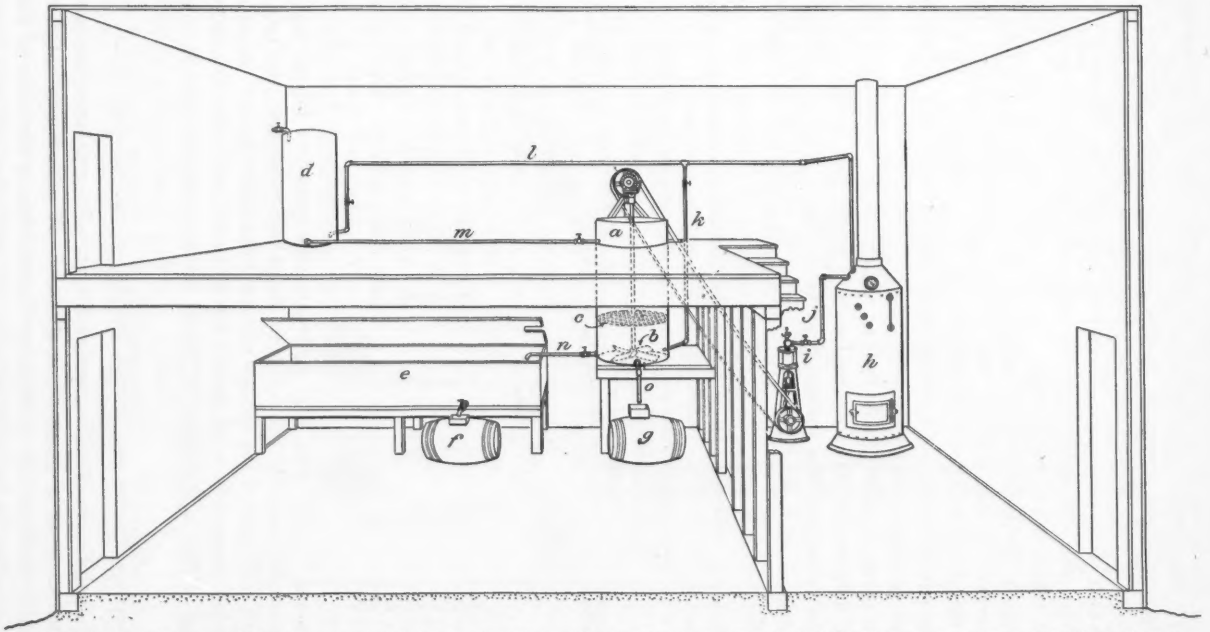

FIG. 12.—Diagrammatic representation of arrangement of parts in a large lime-sulphur cooking plant: *a*, Cooking tank; *b*, agitator; *c*, screen for support of lime and sulphur; *d*, water supply tank; *e*, settling tank; *f*, barrel for storing the lime-sulphur concentrate; *g*, same when concentrate is drawn directly from cooking vessel; *h*, steam boiler; *i*, steam engine for running agitator; *j*, steam pipe from boiler to engine; *k*, steam pipe for cooking the lime-sulphur concentrate; *l*, steam pipe for heating water in water supply tank; *m*, pipe from water supply tank to cooking vat; *n*, pipe and valve for drawing off concentrate from cooking vat to settling tank; *o*, pipe and valve for drawing off concentrate from cooking vat directly to storage barrel. Prepared by E. W. Scott. (Original.)

DILUTION.

It is very important to test with a hydrometer the strength of all lime-sulphur solutions prepared, to determine the proper amount of the concentrate that should be used for a given quantity of water. There are two kinds of these hydrometers, one with the Baumé scale and the other with the specific gravity scale, and hydrometers may be purchased which have both scales on the same instrument. The Baumé scale hydrometer is most commonly used. The clear solution at a temperature of about 60° F. should be used for the testing. If, however, the sludge has not been filtered out, the contents of the barrel or other container should be thoroughly stirred before the required amount for testing is taken out.

Below is given a table (Table I) from which can be determined the amount of dilution for concentrates for each degree Baumé from 20 to 36, and the corresponding specific-gravity reading. Figure 13 illustrates the kind of hydrometers to be used in testing lime-sulphur concentrates.

TABLE I.—*Dilution table for concentrated lime-sulphur solutions.*

Degrees Baumé.	Specific gravity.	Number gallons concentrated lime-sulphur to make 50 gallons spray solution.			Degrees Baumé.	Specific gravity.	Number gallons concentrated lime-sulphur to make 50 gallons spray solution.		
		Summer or foliage strength.	Winter or dormant strength.				Summer or foliage strength.	Winter or dormant strength.	
			San Jose scale.	Blister mite.				San Jose scale.	Blister mite.
36	1.330	1¼	5¼	4¾	27	1.229	2	8	6¾
35	1.318	1¼	5⅓	5	26	1.218	2	8⅓	7¼
34	1.306	1⅓	6	5	25	1.208	2	8¾	7½
33	1.295	1⅓	6¼	5¼	24	1.198	2¼	9¼	8
32	1.283	1⅓	6½	5½	23	1.188	2¼	9½	8¼
31	1.272	1½	6¾	5¾	22	1.179	2¼	10¼	8¾
30	1.261	1½	7	6	21	1.169	2½	11	9¼
29	1.250	1½	7¼	6¼	20	1.160	2½	11½	9¾
28	1.239	1¾	7½	6½					

In spraying for the San Jose scale and the pear-leaf blister mite about 5 per cent more of the solution should be used than the table of dilutions indicates, if the sludge has not been filtered out. In summer spraying, however, no allowance for sludge is necessary, as a large percentage of this is composed of finely divided sulphur, which is of value.

LIME-SULPHUR WASHES FOR SUMMER SPRAYING OF THE SAN JOSE SCALE.

The lime-sulphur washes discussed on the preceding pages are intended for use on trees in a dormant condition. It sometimes happens that owing to unfavorable weather conditions during the time of the dormant spraying, or for other reasons, the insect has not been properly destroyed, and it becomes desirable to spray the trees during the

summer. Under these circumstances much benefit will follow summer spraying for the San Jose scale, but this work should be regarded as a temporary expedient to prevent undue increase of the insect until the more effective dormant treatment may be applied.

Either the commercial or homemade lime-sulphur concentrate may be used for summer spraying (except on stone fruits), but they must be used in a much more dilute condition than during the winter. The dilute lime-sulphur spray has come into very extended use as a fungicide[1] and is used on pome fruits at the rate of 1½ gallons of the concentrate, registering from 32 to 34 degrees on the Baumé scale, to 50 gallons of water. The use of the lime-sulphur wash as a fungicide will constitute sufficient sprayings for the scale, provided attention is given in spraying to coat, in addition to the leaves and fruit necessary in fungicidal work, also the limbs, branches, and twigs.

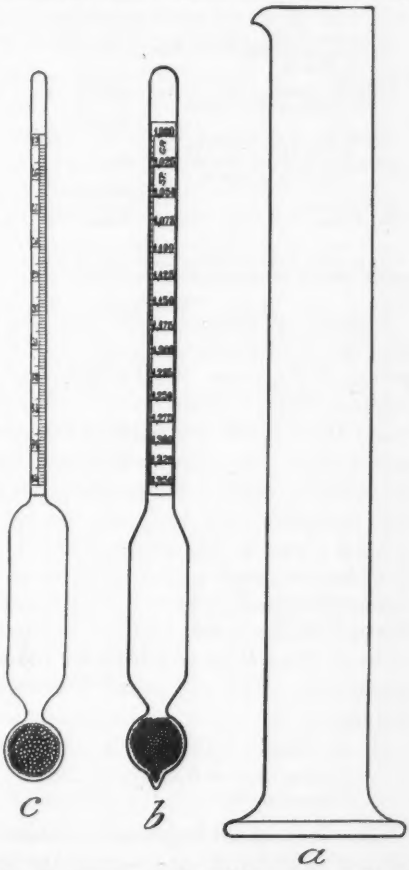

FIG. 13.—Apparatus for determining specific gravity of lime-sulphur concentrate: *a*, Cylinder for liquid to be tested; *b*, specific gravity spindle; *c*, Baumé spindle. (Original.)

Young scale insects from individuals which may have escaped the treatment have a decided tendency to migrate onto the fruit. The presence of these insects on the fruit is very objectionable, especially on apples intended for export trade, as scale-infested fruit is excluded from entry by certain foreign governments, and is discriminated against by buyers generally. The influence of sulphur sprays used as fungicides in trees and foliage in checking the settling of young scales on the fruit is shown in Table II. These data were obtained by Mr. E. W. Scott, of the Bureau of Entomology, in the course of some experimental work during 1911 at Fennville, Mich.

[1] Quaintance, A. L., and Scott, W. M. The more important insect and fungous enemies of the fruit and foliage of the apple. U. S. Dept. Agr., Farmers' Bul. 492, 48 p., 21 figs. 1912.

TABLE II.—*Results of lime-sulphur sprays in preventing marking of fruit by the San Jose scale.*

Plat No.	Treatments.[1]	Variety.	Number of apples infested.	Number of apples not infested.	Total number of apples.	Percentage of uninfested apples.
1	Commercial lime sulphur, 1⅓ to 50; sprayed May 12, 25, June 14, July 25.	Rhode Island Greening.	137	1,606	1,743	92.13
2	....do	Baldwin	80	778	858	90.67
3	Home boiled lime sulphur, May 12, 25, June 14, July 25.	Greening	79	3,939	4,018	98.03
4	....do	Baldwin	37	1,813	1,850	98.00
5	Commercial lime sulphur, 1⅓ to 50; May 12, 25, June 14, July 25.	....do	13	298	311	95.81
6	Bordeaux mixture (3-4-50), May 12, 25, June 14, July 25.	Greening	843	1,055	1,898	55.58
7	....do	Baldwin	525	500	1,025	48.78
8	Unsprayed	Greening	796	805	1,601	50.28
9	....do	Baldwin	809	190	999	19.01

[1] All treatments had 2 pounds of arsenate of lead to each 50 gallons of spray, except in case of plat 5, which had the poison in the application of May 12 only.

Summer spraying of peach trees and other stone fruits for the scale may also be desirable because of ineffective work during the dormant period of the trees. Under such circumstances the self-boiled lime-sulphur mixture should be used, since the foliage of the peach will not stand the diluted lime-sulphur mixture previously indicated for the apple, pear, etc. This self-boiled lime-sulphur wash is made up according to quite a different formula from any of the washes heretofore mentioned, and has come into general use as a fungicide for the control of peach scab and brown-rot.[1] Orchardists spraying for these troubles on peaches and other stone fruits may at the same time accomplish much in preventing the increase of the scale by thoroughly coating the limbs and branches of the trees while making the applications to the foliage and fruit for the control of the fungous troubles mentioned. The self-boiled lime-sulphur wash may be made as follows:

Stone lime	pounds	8
Sulphur (flour or flowers)	do	8
Water to make	gallons	50

The lime should be placed in a barrel and enough water poured on almost to cover it. As soon as the lime begins to slake the sulphur should be added, after first running it through a sieve to break up the lumps. The mixture should be stirred constantly and more water added as needed to form a thick paste at first and then gradually a thin paste. The lime will supply enough heat to boil the mixture several minutes. As soon as it is well slaked water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted, and applied.

[1] Scott, W. M., and Quaintance, A. L. Spraying peaches for the control of brown-rot, scab and curculio. U. S. Dept. Agr., Farmers' Bul. 440, 40 p, 14 figs. 1911.

The stage at which cold water should be poured on to stop the cooking varies with different grades of lime. Some limes are so sluggish in slaking that it is difficult to obtain enough heat from them to cook the mixture at all, while other limes become intensely hot on slaking, and care must be taken not to allow the boiling to proceed too far. If the mixture is allowed to remain hot 15 or 20 minutes after the slaking is completed the sulphur gradually goes into solution, combining with the lime to form sulphids, which are injurious to peach foliage. It is therefore very important, especially with hot lime, to cool the mixture quickly by adding a few buckets of water as soon as the lumps of lime have slaked down. The intense heat, violent boiling, and constant stirring result in a uniform mixture of finely divided sulphur and lime, with only a very small percentage of the sulphur in solution. It should be strained to take out the coarse particles of lime, but the sulphur should be carefully worked through a strainer. The mixture can be prepared in larger quantities if desirable, say enough for 200 gallons at a time, making the formula 32 pounds of lime and 32 pounds of sulphur to be cooked with a small quantity of water (8 or 10 gallons) and then diluted to 200 gallons.

COMMERCIAL POWDERED SULPHUR COMPOUNDS.

Within the past two or three years certain manufacturers have offered for sale, in a dry powdered condition, compounds of sulphur which are to be dissolved in water for the preparation of the spray. These compounds give promise of being satisfactory as scale washes, and if so, will undoubtedly meet with prompt favor with orchardists, since by their use there is a distinct saving in freight, and they are much more convenient in handling and storing.

PETROLEUM-OIL SERIES.

Under the heading "Petroleum-oil series" are to be included kerosene and crude petroleum, either pure or in emulsion, and the so-called miscible oils.

Pure Kerosene.

Pure kerosene has been recommended to a greater or less extent for spraying trees badly infested with the scale, but it has never been very generally employed. There is no question of the efficiency of such an application in the destruction of the insects, but the great danger of injury to the plants precludes its general application. Treatments of pure kerosene should be made only to dormant trees and during bright days and should be applied through a nozzle with a very fine aperture. Only the minimum amount of kerosene necessary to cover the trees should be given, and care is necessary that the liquid does not puddle around the roots of the trees.

Pure Crude Petroleum.

Pure crude petroleum is used in identically the same manner as pure kerosene, and the same cautions as to its use should be remembered. The crude oil employed in the East is known as "insectide oil" and has a specific gravity of 43 to 45 degrees on the Baumé scale.

Kerosene Emulsion (Stock Solution 66 Per Cent Oil).

Kerosene emulsion is made after the following formula:

Kerosene (coal oil, lamp oil)	gallons..	2
Fish-oil soap or laundry soap (or 1 quart of soft soap)	pound..	½
Water	gallon..	1

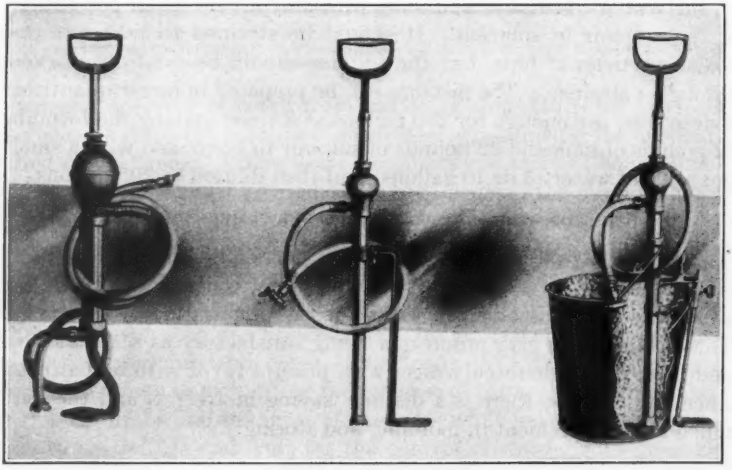

Fig. 14.—Bucket spray pump suitable for use in yards. (Author's illustration.)

Dissolve the soap in boiling water; then remove the vessel from the fire. Immediately add the kerosene and thoroughly agitate the mixture until a creamy solution results. The stock emulsion may be more conveniently made by pouring the mixture into the tank of a spray pump and pumping the liquid through the nozzle back into the tank for some minutes. The stock solution, if well made, will keep for some months, and is to be diluted before using. In order to make a 10 per cent spray (the strength for trees in foliage), add to each 1 gallon of the stock solution about 5⅔ gallons of water. For 20 and 25 per cent emulsions (for use on dormant trees and plants), use, respectively, about 2⅓ gallons and 1⅔ gallons of water for each 1 gallon of stock emulsion. Agitate the mixture in all cases after adding the water. The preparation of the emulsion will be simplified by the use of a naphtha soap. No heat will then be required, as the kero-

sene will combine readily with the naphtha soap in water when thoroughly agitated. Of naphtha soap, however, double the quantity given in the foregoing formula will be required, and soft or rain water should be used in making the emulsion. In regions where the water is "hard" this should first be broken with a little caustic potash or soda, such as common lye, before use for dilution, to prevent the soap from combining with the lime or magnesia present, thus liberating some of the kerosene; or rain water may be employed.

Crude Petroleum Emulsion.

Crude petroleum emulsion may be prepared in identically the same way as described for kerosene emulsion, substituting crude petroleum for kerosene. The same dilutions for winter and summer

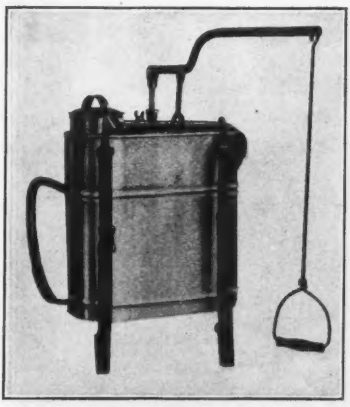

Fig. 15.—Knapsack sprayer suitable for spraying low-growing plants. (Author's illustration.)

Fig. 16.—Barrel sprayer suitable for orchard or similar large-scale work. (Author's illustration.)

spraying should be made as prescribed for kerosene emulsion, but it should be noted that for summer treatments of trees in foliage the kerosene emulsion is preferable, as it is less likely to cause injury.

Miscible Oils.

Under the heading "miscible oils" are to be designated several proprietary preparations which are essentially petroleum oils with the addition of a vegetable oil and an alkali, to secure ready saponification with water. These come in concentrated solutions and the spray is prepared by adding a specified amount of water. In point of convenience they leave little to be desired. Miscible oils have come into use in place of kerosene or crude petroleum, either pure or in emulsions, and have a distinct usefulness as winter sprays about the same as have the concentrated lime-sulphur solutions. As has

been indicated, the petroleum oils are at times the cause of injury to twigs and fruit buds, in extreme cases killing the trees. It is a question of judgment whether, under conditions of severe scale infestation, the petroleum oils or the sulphur solutions should be used. The petroleum oils, on the whole, are more effective and the danger of injury from them is less to pome than to stone fruits.

The practicability of making miscible oils at home has been investigated by Prof. C. L. Penny, and he has shown it to be entirely feasible, as detailed in the publications cited below.[1]

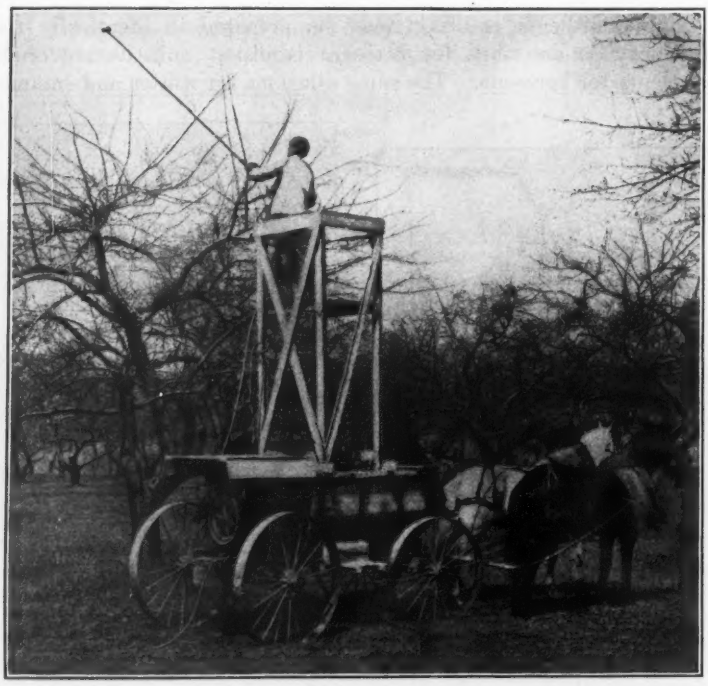

FIG. 17.—Gasoline power spraying outfit for use in large orchards. (Original.)

SOAP WASHES.

Practically the only soap wash which has come into extended use against the San Jose scale is that made from fish oil. Fish-oil soap is used mostly on dormant trees, being employed at the rate of 2 pounds to the gallon of water.

A potash fish-oil soap is preferable and should contain not more than 30 per cent of water. Soda soaps, while perhaps cheaper, will be

[1] Penny, Charles L. Petroleum emulsions. Del. Agr. Col. Expt. Sta., Bul. 75, 39 p., June 18, 1906. Penny, Charles L. Miscible oils: How to make them. Penn. State Col., Bul. 86, 20 p., fig., March, 1908.

likely to solidify on cooling when used at the strength just indicated, and are hence forced through the spray-nozzle with difficulty. For spraying trees in foliage the soap should be used at the rate of 1 pound to 3 or 4 gallons of water, or somewhat weaker.

SPRAYING APPARATUS.

For the successful application of sprays to trees and plants infested with the San Jose scale some form of spraying apparatus is necessary. For small plants, as low trees, ornamental hedges, etc., a bucket pump (fig. 14) or a knapsack pump (fig. 15) will be satisfactory. The barrel pump (fig. 16) will permit of more thorough work and will be suitable for orchards of some size. It may be placed in a wagon or cart or mounted on a sledge. For large commercial orchards the hand-power tank, or gasoline outfits, are, of course, employed. (See fig. 17.) It is quite practicable in case but a few trees in the yard are to be treated to apply the wash on the limbs and branches by means of a brush, or even with old cloths. Fish-oil soap is excellent in such cases. Severe pruning of the trees is usually desirable to simplify the work of treatment, and also to produce a new growth of noninfested wood.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1916

INDEX.

	Farmers' Bulletin No.	Page.
Agelaius spp., feeding habits	630	15–17
Agricultural—		
high schools, laboratory exercises in farm mechanics, bulletin by Daniels Scoates	638	1–26
Outlook—		
December, 1914	645	45
November, 1914	641	40
October, 1914	629	35
Agropyron, spp., food plant of Hessian fly	640	7–9
AINSLIE, GEORGE G., bulletin on "The larger corn-stalk borer"	634	1–8
Air drainage, relation to peach growing, remarks	631	5–6
Alabama—		
cotton production, cost per item	641	14
field crops imported, quantity and value of four products	645	13
game laws for 1914	628	14 30, 36 40, 46
peaches suitable to different sections and time of ripening	633	3
Alaska, game laws for 1914	628	14 30, 36 40, 46
Alberta—		
game laws for 1914	628	6–7, 26 34, 39 43, 53
peach, value and popularity, note	633	3
Alfalfa—		
attacked by clover-root curculio, bulletin by F. M. Webster	649	1–8
crop, damage by grasshoppers	637	2
culture and the grasshopper problem, bulletin by F. M. Webster	637	1–10
fields—		
flooding for destruction of grasshoppers	637	8
treatment for control of chalcis-fly	636	6–9
harvesting for control of chalcis-fly	636	6
hay—		
prices paid producers, averages for specific dates	641	38
prices paid producers, by States	641 645	36 41
prices paid producers on specified dates	645	43
injury from clover-root curculio, nature and extent	649	5–6
seed—		
chalcis-fly, bulletin by Theodore D. Urbahns	636	1–10
prices paid by farmers	629 641 645	30 37, 38 42, 43
prices paid producers, by States	641 645	36 41
yield and production, by States	629	24
Algeria, citrus fruit prospect, 1914–1915	629	13
Almonds, crop conditions on specific dates	629	12
Andrews, Frank—		
article on "The cotton crop surplus"	641	9–12
estimates of Louisiana sugar cane, 1914	641	5–6
preliminary estimate of sugar beets and beet sugar, 1914	641	4–5
statistics on "Relative production of apple varieties"	641	16–19
Animals, total value (with animal products), 1887–1914, yearly	645	6–7
Anthrenus lepidus, note	626	2
Anthrenus scrophulariæ. *See* Carpet beetle.		
Ants, forest, destruction by woodpeckers	630	25

	Farmers' Bulletin No.	Page.
Aphelocoma californica, feeding habits	630	20–21
Apple—		
trees, injury from San Jose scale, appearance and damage	650	2–3, 5
varieties, relative production by States	641	16–19
Apples—		
acreage, 1914	629	2
cold-storage holdings	645	14–15
consumption per capita by farmers, ten States	635	11, 12
crop condition on specific dates, comparisons	629	2
crop conditions and prices by States	629	25
farm prices on specific dates	629	30
prices paid producers, averages for specific dates	641	38
prices paid producers, by States	645	39
prices paid producers on 15th of each month, 1910–1914	645	10
prices paid producers on specific dates	645	43
production and prices, 1909–1914, by States	645	8–9
production by States, percentage of varieties	641	17–18
production of different varieties by States	641	19
production, quality and prices	641	2, 30
yield, production and prices, 1913, 1914	629	3
Apricots, crop conditions on specific dates	629	12
Argentina—		
food production and requirements	641	21
foodstuffs, production, imports and exports, items	641	22
wheat—		
acreage, production, and export, yearly, 1892–1915	645	17
crop, outlook	641	7–9
crops, 1912–1914	641	9
industry, remarks	645	16–17
production, 1912–1914	629	6
Arizona—		
crops, acreage, yield, production, prices, and value	645	24, 25 27–29 32, 34
game laws for 1914	628	15 30, 36 40, 46
Arkansas—		
apple crop, percentage of different varieties	641	17
cotton production, cost per item	641	14
crops, acreage, yield, production, prices, and value	645	24 25, 27 28, 30 32–36
field crops imported, quantity and value of four products	645	13
game laws for 1914	628	15 30, 36 40, 46
kingbird, feeding habits	630	23–24
peaches suitable to different sections and time of ripening	633	3
Asparagus, growing in home garden, directions and varieties recommended	647	11
Aspidiotus perniciosus. *See* San Jose scale.		
Australia—		
wheat crops, 1912–1914	641	9
wheat production 1912–1914	629	6
Austria-Hungary—		
food production and requirements	641	21
foodstuffs, production, imports and exports, items	641	22
Bag limits, regulations for 1914, by States	628	39–43
Baltimore oriole, usefulness to farmer, feeding and nesting habits	630	13
BANCROFT, W. F., T. S. PALMER, and FRANK L. EARNSHAW, bulletin on "Game laws for 1914: A summary of the provisions relating to seasons, export, sale, limits, and licenses"	628	1–54
Bank swallow, note	630	8

	Farmers' Bulletin No.	Page.
Barley—		
acreage, production, and farm value	645	4
acreage, yield, production, and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	29
farm prices on specific dates	645	23
prices paid producers, averages for specific dates	641	38
prices paid producers, by States	641	33
prices paid producers on specific dates	645	43
production in leading five States	645	5
shipment from California to New York	645	13
weight to the measured bushel, by States	641	29
yield, production, and prices, 1913, 1914	629	3
yield, production, quality, and price, by States	629	21
yield, production, quality, and prices	641	2
Barn swallow, feeding and nesting habits	630	8, 9
BEAL, F. E. L., bulletin on "Some common birds useful to the farmer"	630	1–27
Beans—		
dry, prices paid producers, by States	641	35
farm prices on specific dates	629	30
growing in home garden, directions and varieties recommended	647	12
prices paid producers, average, for specific dates	641	38
prices paid producers, by States	645	40
prices paid producers on specific dates	645	43
production by States	629	26
soy. *See* Soy beans.		
Beef, consumption per capita on farm	635	2
Beetle, carpet, or "buffalo moth," bulletin by L. O. Howard	626	1–4
Beets—		
growing in home garden, directions	647	12
sugar—		
acreage, production and farm value	645	4
crop on specific dates, by States	629	27
production, 1914, estimates	641	4–5
production in leading five States	645	5
yield, production and quality	641	2
Belgium—		
foodstuffs, production, imports and exports, item	641	22
wheat crops, 1912–1913	641	9
Benzine, use against carpet beetle	626	3
Berckmans, P. J., introduction of Peen-to peach	633	12
BESSEY, ERNEST A., and L. P. BYARS, bulletin on "The control of root-knot"	648	1–19
Big-root. *See* Root-knot.		
Birds—		
enemies of clover-root curculio	649	7
enemies to grasshoppers	637	4
land, feeding habits, remarks	630	1–2
migratory, appropriation for protection	628	5
migratory, proclamation for protection, text	628	9–13
useful to farmer, occurrence and feeding habits of various species	630	1–27
useful to the farmer, some common, bulletin by F. E. L. Beal	630	1–27
Bisulphid of carbon, use against carpet beetle	626	4
Black—		
phœbe, feeding and nesting habits	630	22–23
walnuts. *See* Walnuts.		
Blackberries—		
acreage (with dewberries), by States	643	1
cultivated fruit, superiority	643	2
growing, soil requirements and preparation	643	2–3
harvesting, suggestions and caution	643	8
mulching, advantages	643	8
planting, cultivation, and fertilizing	643	4–5
propagation methods	643	3
pruning, need, directions	643	5–6
training systems	643	6–7
varieties, descriptions, and characteristics	643	11–13
varieties for different regions	643	10–11
winter protection	643	9

	Farmers' Bulletin No.	Page.
Blackberry—		
by-products	643	12
culture, bulletin by George M. Darrow	643	1–15
growing, intercrops suitable	643	4
plantation, care, duration, etc	643	8–10
plantation, location and soil selection	643	2–3
Black-billed cuckoo, feeding habits	630	27
Blackbirds—		
red-winged, usefulness to farmer, feeding habits	630	15–17
usefulness to farmer, feeding habits of various species	630	12–13, 15–17
Blue jay, usefulness to farmer, objection, feeding habits, etc	630	19–20
Bluebird—		
eastern, feeding habits	630	2–3
mountain, feeding habits	630	3
western, feeding habits	630	3
Bluebirds, usefulness to farmer, feeding habits, varieties	630	2–3
Board, farm, cost, estimate, and remarks	635	19–20
Bobolink, usefulness to farmer, feeding habits	630	17
Bœotomus subapterus, enemy of Hessian fly, note	640	16
Bordeaux mixture, formula	642	10
Bottling grape juice, directions	644	6–7
Bran—		
prices paid by farmers	641	38
prices paid by farmers, by States	641, 645	37, 42
prices paid by farmers on specific dates	629, 645	30, 43
Brewer blackbird, usefulness to farmer, feeding habits	630	12–13
British Columbia, game laws for 1914	628	7, 26, 32, 43, 53
British India—		
cotton acreage, 1915	629	11
wheat crops, 1912–1914	641	9
wheat production, 1912–1914	629	6
Broom corn—		
farm prices on specific dates	629	30
prices paid producers, averages for specific dates	641	38
prices paid producers by States	645	40
prices paid producers on specific dates	645	43
yield and production by States	629	27
Brown thrasher, usefulness to farmer, feeding and nesting habits	630	7
Bruchophagus funebris. *See* Chalcis fly.		
Buckwheat—		
acreage, 1914	629	2
acreage, production and farm value	645	4
acreage, yield, production, and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	31
crop condition and prices on specific dates, by States	629	23
crop condition on specific dates, comparisons	629	2
farm prices on specific dates	645	23
prices paid producers on specific dates	641, 645	38, 43
production in leading five States	645	5
yield, production, and prices, 1913–1914	629	3
yield, production, quality, and prices	641	2
yield, production, quality, and prices, by States	641	28
Budding—		
peach stock, practices	631	9
peach trees, methods	632	12–13
"Buffalo moth"—		
or the carpet beetle, bulletin by L. O. Howard	626	1–4
See also Carpet beetle.		
Buildings, farm, exercises in construction for agricultural schools	638	11–14
Bulgaria, wheat crops, 1912–1914	641	9

	Farmers' Bulletin No.	Page.
Bull-bat, usefulness to farmer, feeding habits	630	24–25
Bullock oriole, usefulness to farmers, feeding and nesting habits	630	14
Bur clover, destruction in control of chalcis fly	636	9
Butter—		
consumption per capita by farmers, 10 States	635	11
prices, by States	629	29
prices paid producers, by States	641	33
prices paid producers on specific dates	641	38
	645	43
prices, range at market centers	641	39
	645	44
Byars, L. P., and Ernest A. Bessey, bulletin on "The control of root-knot"	648	1–19
Cabbage—		
acreage, yield and production by States of surplus production	645	11, 12
farm prices on specific dates	629	30
growing in home garden, directions and varieties recommended	647	12–13
prices paid producers—		
averages for specific dates	641	38
by States	641	35
	645	40
on specific dates	645	43
production and prices by States	629	26
California—		
apple crop, percentage of different varieties	641	17
barley shipments to New York	645	13
crop conditions on specific dates	641	6
crop report	645	10
crops—		
acreage, yield, production, prices and value	645	24, 25, 28–30, 32–34, 36
condition on specific dates	629	12
game laws for 1914	628	15, 30, 37, 40, 46
jay, feeding habits, damage to orchard fruits	630	20–21
peaches suitable to different sections, and time of ripening	633	4
Calves—		
farm prices on specific dates	629	30
prices paid producers—		
averages for specific dates	641	38
by States	641	34
	645	38
on specific dates	645	43
Canada—		
crop report, 1914	641	23–24
crops, acreage and production of various kinds, estimates for 1914	629	14–15
food production and requirements	641	21–22
foodstuffs, production, imports and exports, items	641	22
game laws passed in 1914, by provinces	628	6–7
wheat crops, 1912–1914	641	9
wheat production, 1912–1914	629	6
Canadian peas, crop condition on specific dates, by States	629	24
Cane—		
sugar—		
crop condition on specific dates, by States	629	27
damage by larger corn-stalk borer	634	1
Louisiana crop, 1914, estimates	641	5–6
yields in Louisiana, forecast	645	10
Cantaloupe growing in home garden, directions and varieties recommended	647	17–18

	Farmers' Bulletin No.	Page.
Carpet beetle—		
description and nature of damage	626	1–2
distribution, history, and habits	626	1–3
introduction into United States, note	626	2
or "buffalo moth," bulletin by L. O. Howard	626	1–4
remedies and preventives	626	3–4
Carpets—		
damage by carpet beetle	626	1
treatment, laying, etc., for extermination of carpet beetle	626	3–4
Carpodacus mexicanus frontalis, feeding habits	630	11–12
Carrots, growing in home garden, directions and varieties recommended	647	13
Carver, T. N., article on "Taking pains"	629	15–17
Cassin kingbird, feeding habits	630	24
Catbird, usefulness to farmer, feeding and nesting habits	630	7–8
Cattle—		
casting, directions	638	5
consumption of various feed crops per annum	629	8
farm prices on specific dates	629	30
prices—		
by States	629	28
paid producers, averages for specific dates	641	38
paid producers, by States	641 645	34 38
paid producers on specific dates	645	43
tick—		
eradication necessary for profitable dairying, bulletin by J. H. McLain	639	1–4
See also Tick, cattle.		
Cauliflower—		
growing in home garden, directions and varieties recommended	647	13–14
preparation for table	647	13–14
Celery, growing on home garden, directions and varieties recommended	647	14
Centipede, house, bulletin by C. L. Marlatt	627	1–4
Chalcis fly—		
control in alfalfa fields, methods	636	6–10
development in alfalfa seed, habits and distribution	636	2–3
in alfalfa seed, bulletin by Theodore D. Urbahns	636	1–10
injury to alfalfa seed, character, and extent	636	3–5
Cheese, prices, range at New York	641 645	39 44
Chestnuts, prices paid producers—		
averages for specific dates	641	38
by States	641 645	37 39
on specific dates	645	43
Chewink, usefulness to farmer, feeding and nesting habits	630	9
Chickadee, Carolina, feeding habits	630	5
Chickens—		
prices by States	629	29
prices paid producers—		
by States	641 645	33 42
on specific dates	645	43
Chinese scale. *See* San Jose scale.		
Chipping sparrow, feeding habits	630	9–10
Chordeiles virginianus, feeding habits	630	24–25
Cider press, homemade, description	644	7–8
Citrus fruits—		
crop condition, California and Florida, specific dates	629 641 649	12 6 10
prospects in Mediterranean countries, 1914–1915	629	12–14
Cliff swallow, feeding and nesting habits	630	8, 9
Clothing, farmers', prices and comparisons, 1899–1913	645	19

	Farmers' Bulletin No.	Page.
Clover—		
crimson—		
care of seed	646	8
effect on soil	646	1
growing for seed, and for hay, as money crop, comparison	646	11–12
growing for seed, directions	646	10–11
seed—		
commercial growing	646	8–11
production, bulletin by J. M. Westgate	646	1–13
seeding—		
in corn crop	646	1
methods	646	2
value for poor and washed soil	646	1
culture in the East, grasshopper control	637	1–10
hay—		
prices paid producers—		
averages for specific dates	641	38
by States	641	36
	645	43
on specific dates	645	43
seed—		
crop condition on specific dates, by States	629	24
farm prices on specific dates	629	30
prices paid by farmers	641	38
prices paid by farmers, by States	641	37
	645	42
prices paid by farmers on specific dates	629	30
	645	43
prices paid producers, by States	645	41
yield, production, and prices, by States	641	81
Clover-root curculio—		
alfalfa attacked by, bulletin by F. M. Webster	649	1–8
enemies	649	6–7
food plants	649	5–6
historical notes, description, etc	649	1–3
life history and habits	649	3–5
preventive and remedial measures	649	7–8
Clover-seed chalcis fly in alfalfa seed, bulletin by Theodore D. Urbahns	636	1–10
Club-root. *See also* Root-knot.		
Coal and wood, consumption per capita on farm	635	2
Coccyzus americanus, feeding habits	630	27
Codling-moth larvæ, consumption by bush tit	630	6
Coffee, consumption per capita by farmers, 10 States	635	11
Colaptes spp., feeding habits	630	26
Collards, growing in home garden	647	14–15
Colorado—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24–30, 32, 34
game laws for 1914	628	15, 30, 37, 40, 46
peaches suitable to different sections, time of ripening	633	4
Comb stripper, homemade, for harvesting crimson clover seed	646	2–6
Connecticut—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24, 28, 30, 31, 32, 34
game laws for 1914	628	16, 30, 37, 40, 46
peaches suitable for different sections, time of ripening	633	5
Cooperation, marketing cotton	641	14–16
Corking machine, description	644	7

	Farmers' Bulletin No.	Page.
Corn—		
acreage, 1914	629	2
acreage production and farm value	645	4
acreage, yield, production, and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	24
crop condition on specific dates, comparisons	629	2
farm prices on specific dates	645	23
forecast of crop and price, by States	629	19
injury by larger corn stalk-borer	634	1–2
interplanting in peach orchard, suggestions	632	19
prices—		
paid producers, averages for specific dates	641	38
paid producers on specific dates	645	43
range at market centers	629	30
	641	39
	645	44
production in leading five States	645	5
purchasing power of 1 acre, 1899–1913	645	21
shipped into cotton States, quantity and value, by States	645	13
stalk-borer, larger—		
bulletin by George G. Ainslie	634	1–8
enemies and preventive measures	634	7–8
habits, seasonal history, description, etc	634	2–7
introduction into United States, note	634	1
nature of damage, distribution	634	1–2
sweet, growing in home garden, gathering, varieties recommended, etc	647	15
yield—		
production and prices, 1913, 1914	629	3
production, quality, and prices	641	2
production, stocks on farms, prices, etc., by States	641	25
Corncobs, consumption for fuel, practices	635	14
Cotton—		
acreage, 1914	629	2
acreage and yield, 1914, by States	629	10–11
acreage, production, and farm value	645	4
acreage, yield, production, and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	36
British India, acreage, 1915	629	11
buyers, practices	641	16
cost of production, article by Nat C. Murray	641	12–14
cost per acre, distribution among items, by States	641	14
crop—		
condition and farm prices on specific dates, by States	629	9–10
condition on specific dates, comparisons	629	2
movement	641	10–11
surplus, article by Frank Andrews	641	9–12
domestic consumption, 1881–1910	641	11
exports and prices, 1910–1914	641	11
exports, by countries to which consigned, 1911–1914	641	12
farm prices on specific dates	645	23
marketing	641	14–16
prices paid producers—		
averages for specific dates	641	38
by States	641	33
on specific dates	645	43
production in leading five States	645	5
purchasing power of 1 acre, 1899–1913	645	21
regions, weather conditions, diagram	629	32
root-knot, relation to wilt	648	3
States—		
agricultural products shipped into	645	12–13
production of field crops consumed, percentage	645	12–13
storage, advantages of common warehouse	641	16
yield, production, and prices	641	2

	Farmers' Bulletin No.	Page.
Cottonseed—		
farm prices on specific dates	629	30
meal—		
prices paid by farmers, by States	641	37
	645	42
prices paid by farmers on specific dates	645	43
prices paid producers—		
averages for specific dates	641	38
by States	641	36
	645	41
on specific dates	645	43
Cover crops—		
for orchards, quantity of seed per acre	631	22
for peach orchards	631	21
Cowpeas, forage production, by States	641	32
Cows—		
consumption of various feed crops per annum	629	8
dipping, effect on milk production	639	2
farm prices on specific dates	629	30
milch, prices, by States	629	28
prices paid producers—		
averages for specific dates	641	38
by States	641	34
	645	38
on specific dates	645	43
spraying, effect on milk production	639	2
tick infestation, effect on milk production and weight of cow	639	1–2
tick infested, losses in milk and weight	639	1–2, 3–4
Cranberries—		
crop condition on specific dates, by States	629	27
production and quality, by States	641	31
"Criddle mixture," use against grasshoppers	637	9
Crimson clover. *See* Clover, crimson.		
Crop—		
production, averages, by States	641	3
report of International Institute of Agriculture, for 1914	641	23
reports, December, time of issuance and scope	641	1
review, November 1, 1914	641	1–4
summary, 1914	645	1
Crops—		
acreage, yield, and farm value	645	4
acreage, yield, production, prices, and value, by States	645	34–36
condition and change during September, 1914, by States	6	4
condition, October 1, 1914, review	629	1–4
farm prices on specific dates	645	23
forecasts and preliminary estimates	641	4
production—		
and rank in production, by States, diagram	645	44
in leading five States	645	5
percentage of full crop	641	3
yield, value per acre, and prices, 1914	645	1–3
purchasing power of 1 acre, 1899–1913	645	21
subject to root-knot	648	8–9
total value, 1887–1914, yearly	645	6–7
value per acre of 10 combined, 1866–1914, yearly	645	23
yield per acre, percentage of normal, diagram	641	40
Crow—		
blackbird, usefulness to farmer, feeding habits	630	12
usefulness to farmer, objections, feeding habits, etc	630	17–19
Cuckoos, usefulness to farmer, feeding habits	630	27
Cucumber vines, protection from beetle	647	16
Cucumbers, growing in home gardens, directions and varieties recommended	647	15–16
Curculio, clover-root, alfalfa attacked by, bulletin by F. M. Webster	649	1–8
Cyanocitta stelleri, feeding habits	630	20–21
Cyanocytta cristata, feeding habits	630	19–20

	Farmers' Bulletin No.	Page.
Dairy products, consumption per capita on farm	635	2
Dairying, profitable, necessity for eradication of the cattle tick, bulletin by J. H. McLain	639	1-4
DARROW, GEORGE M., bulletin on "Blackberry culture"	643	1–15
Daugherty, Charles M.—		
article on "The world wheat crop in 1914"	629	6–7
article on "The world's wheat"	641	7–9
statements and statistics on "Wheat crop of the Southern Hemisphere"	645	15–17
Delaware—		
crops, acreage, yield, production, prices, and value	645	24, 25, 27, 28, 30–34
game laws for 1914	628	16, 30, 37, 40, 46
peaches suitable to different sections, time of ripening	633	5
Denmark, wheat crops, 1912–1914	641	9
Dewberries, acreage (with blackberries), by States	643	1
Diatraee saccharalis. *See* Cornstalk borer, larger.		
District of Columbia, game laws for 1814	628	16, 40
Dolichonyx oryzivorus, feeding habits	630	17–19
Downy woodpecker, feeding habits	630	25
Drains, farm, exercises for agricultural schools	638	21–23
Dryobates spp., feeding habits	630	25
Dumetalla carolinensis, usefulness to farmer, feeding and nesting habits	630	7–8
EARNSHAW, FRANK L., T. S. PALMER, and W. F. BANCROFT, bulletin on "Game laws for 1914: A summary of the provisions relating to seasons, export, sale, limits, and licenses"	628	1–54
Eastern kingbird, feeding habits	630	23–24
Eelworm. *See* Gallworm.		
Eggplant, growing in home garden, directions and varieties recommended	647	16
Eggs—		
and poultry, consumption per capita on farm	635	2
consumption per capita, by farmers, 10 States	635	11
prices, by States	629	29
prices paid producers, by States	641	33
	645	42
prices paid producers on specific dates	641	38
	645	43
prices, range at market centers	641	39
	645	44
England, food production and requirements	641	20
English sparrow, note	620	10
Eupelmus allynii, parasite of Hessian fly, description notes	640	15–16
Euphagus cyanocephalus, feeding habits	630	12–13
Europe—		
wheat crop, outlook	641	8–9
wheat production by countries, 1912–1914	629	7
Farm—		
contributions, directly to farmer's living, bulletin by W. C. Funk	635	1–21
family, cost of living for each member, estimates	635	2
living, cost per capita, 10 States	635	20
mechanics, laboratory exercises for agricultural high schools, bulletin by Daniels Scoates	638	1–26
products—		
farm prices, by States	629	28–29
	645	38–42
farm prices on specific dates	629	30
prices paid producers, averages for specific dates	641	38
prices paid producers, by States	641	33–38
prices, range at market centers	629	30
	641	39

	Farmers' Bulletin No.	Page.
Farm—Continued.		
products—Continued.		
prices, trend	629	14
	641	7
	645	12
total value, 1887–1914	645	6–7
value, discussion and statistics	645	6–7
See also under name of specific product.		
Farmer—		
animal products consumed, amounts raised and bought, 10 States	635	9
birds useful, some common, bulletin by F. E. L. Beal	630	1–27
contributions to living by farm, bulletin by W. C. Funk	635	1–21
food consumption, per family and per capita	635	7, 8
fruits consumed, amounts grown and bought, 10 States	635	9
groceries consumed, amounts grown and bought, 10 States	635	9, 10
living expenses—		
contribution from farm	635	1–21
purchases per family and per capita	635	6
vegetables consumed, amounts grown and bought, 10 States	635	9
Farmers—		
purchasing power, remarks and statistics	645	19–23
supplies, prices of articles, with comparisons, 1899–1913	645	19–20
Farming, value of "taking pains," article by T. N. Carver	629	15–17
Feed crops—		
consumption of various kinds by man, per annum	629	8
disposition, article by Nat C. Murray	629	8–9
distribution on farms	629	9
fed on farms, quantity and value per capita of live stock	629	9
Fermentation, grape juice, cause, nature, and preventive methods	644	3
Fertilizer, formula for home garden	647	7
Fertilizers—		
use on peach orchards	631	23–24
vegetable garden, requirements and use	647	6–8
Field sparrow, feeding habits	630	9–10
Filters, grape juice, descriptions	644	5–7
Finch, house, usefulness to farmer, feeding habits	630	11–12
Fining grape juice, practices	644	12–13
Flax—		
acreage, 1914	629	2
crop conditions on specific dates, comparisons	629	2
Flaxseed—		
acreage, production and farm value	645	4
acreage, yield, production and value, 1899–1914	645	22
acreage, yield, production, prices and value by States	645	35
condition, forecast and prices, by States	629	20
farm prices on specific dates	645	23
prices paid producers, averages for specific dates	641	38
prices paid producers on specific dates	645	43
production in leading five States	645	5
stages of Hessian fly, notes	640	3, 4
yield, production, and prices, 1913, 1914	629	3
yield, production, quality, and prices	641	2
yield, production, quality, and prices, by States	641	28
Flicker, usefulness to farmer, feeding habits	630	26
Florida—		
crop conditions on specific dates	629	12
	641	6
crop report	645	10
crops, acreage, yield, production, prices, and value	645	24, 28, 32–36
field crops imported, quantity and value of four products	645	13
game laws for 1914	628	16, 30, 37, 40, 47
peaches suitable to different sections, time of ripening	633	5
Flour, consumption per capita by farmers, 10 States	635	11

	Farmers' Bulletin No.	Page.
Fly, Hessian—		
bulletin by F. M. Webster	640	1–20
See also Hessian fly.		
Food—		
consumption by farm family, owned and rented farms	635	20
consumption by farm family, 10 States	635	7–14
cost per capita to farmers, relation to size of family, 10 States	635	14
farmer, consumption per family and per capita	635	7, 8
farmer, value of purchases, per family and per capita	635	7
production and requirements of various countries, statements by Nat C. Murray	641	20–23
production and requirements, United States	641	21
Foodstuffs, production, imports and exports, United States, items	641	22
Fox sparrow, note	630	10
France—		
food production and requirements	641	21
foodstuffs, production, imports and exports, items	641	22
wheat crops, 1912–1914	641	9
Freight rates, ocean, wheat from New York to Liverpool	645	7
Fruit—		
consumption per capita on farm	635	2, 11, 12
farm prices for various kinds, on specific dates	629	30
prices paid producers, by States	645	39
See also under name of specific product.		
Fruits—		
citrus, Florida and California crop report	645	10
destruction by house finch	630	11–12
destruction by jays	630	20–21
prices paid producers, averages for specific dates	641	38
subtropical, crop conditions in Florida and California	629	12, 14
Fuel—		
consumption per capita on farm	635	2
consumption per farm family and per capita, amount bought, etc., 10 States	635	14–15
Funk, W. C., bulletin on "What the farm contributes directly to the farmer's living"	635	1–21
Gallworm—		
description, injury to plants, etc	648	4–6
life history and habits	648	4–6
Game—		
bag limits, new legislation for 1914	628	3
export and sale, new legislation for 1914	628	3
laws—		
Federal, passed in 1914	628	5
for 1914: A summary of the provisions relating to seasons, export, sale, limits, and licenses	628	1–54
harmonizing State and Federal, efforts in several States	628	2–3
passed in 1914, by States and provinces	628	5–7
legislation, 1914, bills which failed to pass, by States	628	7–8
licenses, new legislation for 1914	628	4
open season, new legislation	628	3
open seasons, United States and Canada, by States and provinces	628	13–28
refuges and farms, new legislation for 1914	628	4
sale regulations, by States	628	35–39
shipment, regulations, Federal and State	628	28–35
shipping regulations for 1914, by States	628	43–54
warden service, new provisions for 1914	628	4
Garden—		
home—		
arrangement of crops, suggestions	647	3–5
in South, bulletin by H. C. Thompson	647	1–28
profitableness	647	1–2
location, drainage requirements, etc	647	2
plants, transplanting, hardening off and setting in open, suggestions	647	9–10
products, consumption per capita on farm	635	2

	Farmers' Bulletin No.	Page.
Gardeners, planting table for vegetables	647	28
Garlic, growing in home garden	647	15
Georgia—		
apple crop, percentage of different varieties	641	18
cotton production, cost per item	641	14
crops, acreage, yield, production, prices and value	645	24, 25, 27, 28, 30, 32–36
farmer, living expenses furnished by farm, per family and per capita	635	5
farmer, living expenses, purchases per family and per capita	635	6
field crops imported, quantity and value of four products	645	13
food consumption by farmer, per family and per capita	635	7, 8
game laws for 1914	628	16, 30, 37, 40, 47
peaches suitable to different sections, time of ripening	633	5
Germany—		
food production and requirements	641	20–21
foodstuffs, production, imports and exports, items	641	22
Gingseng plantations, root-knot control	648	13–14
Golden-winged woodpecker, usefulness to farmer, feeding habits	630	26
GOULD, H. P., bulletin on—		
"Growing peaches: Pruning, renewal of tops, thinning, interplanted crops, and special practices"	632	1–23
"Growing peaches: Sites, propagation, planting, tillage, and maintenance of soil fertility"	631	1–24
"Growing peaches: Varieties and classification"	633	1–13
Grackles, usefulness to farmer, feeding habits and objections	630	12
Grafting peach trees	632	12–13
Grain—		
crops, Canada, acreage and production, 1914, estimates	629	14–15
crops, yield, production, quality, and prices	641	2
prices paid producers on specific dates	641	38
	645	43
See also Barley; Buckwheat; Corn; Oats; Rye; Wheat.		
Grains, yields, report of International Institute of Agriculture	645	8
Grape—		
California vinifera varieties, analysis of must	644	2
composition	644	2
concord, analysis of must	644	2
juice—		
clarifier, description	644	15
clarifying, method	644	12–13
color control	644	6, 9
flavor and quality, influences	644	4
home manufacture, directions	644	5–8
pasteurizer, description and management	644	6
quality of different varieties	644	4
sugar content of products of different varieties of grapes, comparisons	644	5
unfermented, food value and uses	644	14–16
unfermented, manufacture and use, bulletin by George C. Husmann	644	1–16
unfermented, manufacture, commercial methods	644	8–13
juices, fermentation, cause, nature, and preventive methods	644	3
nectar, recipe	644	15
presses, manufacture of grape juice, descriptions	644	8–12
Grapefruit, crop conditions on specific dates	629	12
	641	6
	649	10
Grapes—		
crop conditions on specific dates	629	12
crop conditions on specific dates, by States	629	25
juices of different varieties, characteristics	644	4, 5

	Farmers' Bulletin No.	Page.
Grapes—Continued.		
pressing for grape juice, household methods	644	5
prices paid producers, by States	641	35
	645	39
production, by States	641	30
yield, production, and quality, in California	645	10
Grasshopper—		
depredations in alfalfa fields, preventive measures	637	7–10
depredations on alfalfa crops, outbreaks	637	3
differential, description, distribution, life history, and habits	637	2, 3–4
mite, enemy of grasshopper, importance, method of destruction, etc.	637	4–5
problem and alfalfa culture, bulletin by F. M. Webster	637	1–10
Rocky Mountain, illustration	637	3, 4
two-striped, description, distribution, life history and habits	637	3–4
Grasshoppers—		
enemies	637	4–6
fungous disease	637	5, 7
species injurious to alfalfa	637	1
Great Britain—		
wheat crops, 1912–1914	641	9
wheat production, 1912–1914	629	7
Greece, citrus fruit propects, 1914–1915	629	13
Greenhouses, control of root-knot	648	12–13
Groceries, consumption per capita on farm	635	2
Gumbo, growing in home garden, directions and varieties recommended	647	18
Hairy woodpecker, feeding habits	630	25
Halter, rope, directions for tying	638	5
Harrowing peach orchard, management in West Virginia	631	20
Harvest, wheat, movement in Southern Hemisphere	645	15–16
Harvesting—		
blackberries, suggestions, and caution	643	8
crimson clover seed, practices and devices	646	2–10
tomatoes, management	642	10–11
Hay—		
acreage, production, and farm value	645	4
acreage, yield, production, and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	34
farm prices on specific dates	645	23
prices by States	629	29
prices paid producers, by States	641	33, 36
	645	41
prices paid producers on specific dates	641	38
	645	43
prices, range at Chicago	645	44
production in leading five States	645	5
shipped into cotton States, quantity and value, by States	645	13
yield, production, and prices, 1913, 1914	629	3
yield, production, quality, and prices	641	2
Hemp, yield, and production	641	2
Hessian fly—		
bulletin by F. M. Webster	640	1–20
description, life history, and distribution	640	2–7
effect of weather conditions on development, experiments	640	11–14
food plants	640	7–9
injury to wheat, nature and processes	640	3–4
introduction into United States	640	2
natural enemies	640	14–16
parasites	640	14–16, 17
remedial and preventive measures	640	16–20
stages of development, description	640	2–3, 4–6
Heterodera radicicola. *See* Gallworm.		
Hickory nuts—		
prices paid producers, by States	641	37
	645	39
prices paid producers on specific dates	641	38
	645	43

	Farmers' Bulletin No.	Page.
Hirundo erythrogastra, feeding and nesting habits	630	8, 9
Hobble, rope, directions for making	638	5–6
Hogs—		
farm prices on specific dates	629	30
prices by States	629	28
prices paid producers, by States	641	34
	645	38
prices paid producers on specific dates	641	38
	645	43
prices, range at Chicago	641	39
	645	44
Honey—		
comb—		
and extract, prices paid producers, by States	641	36
	645	40
and extract, prices paid producers on specific dates	641	38
	645	43
farm prices on specific dates	629	30
Hopperdozer—		
construction and equipment	637	8–9
use against grasshoppers	637	8–9
Hops—		
consumption and movement, 1906–1914	641	6
farm prices on specific dates	629	30
prices paid producers, by States	645	39
prices paid producers on specific dates	641	38
	645	43
prices, range at New York	645	44
yield and quality, by States	629	27
Horse, casting, directions	638	5–6
Horses—		
consumption of various feed crops per annum	629	8
farm prices on specific dates	629	30
prices, by States	629	28
prices paid producers, by States	641	34
	645	38
prices paid producers on specific dates	641	38
	645	43
Hotbed—		
making, directions	647	8–9
tomato, directions for making	641	1–3
House—		
centipede—		
bite, danger and treatment	627	4
bulletin by C. L. Marlatt	627	1–4
description and food habits	627	2–4
distribution	627	2
extermination	627	4
life history	627	3–4
occurrence, habits, and distribution	627	1–3
poisonous nature, destruction of household insects, etc	627	3–4
cleaning, management for extermination of carpet beetle	626	3–4
finch, usefulness to farmer, feeding habits	630	11–12
rent—		
farm dwellings, estimates, and considerations	635	16–17
per capita on farm	635	2
Household—		
articles, prices, and comparisons, 1899–1913	645	19–20
insects, carpet beetle, or buffalo moth	626	1–4
insects, house centipede	627	1–4
labor, farm, relation of cost to size of family	635	17–18, 20
Howard, L. O., bulletin on "The carpet beetle, or buffalo moth"	626	1–4
Hungary—		
wheat crops, 1912–1914	641	9
wheat production, 1912–1914	629	7

	Farmers' Bulletin No.	Page.
Hunting licenses, regulations for 1914, by States	628	43–54
HUSMANN, GEORGE C., bulletin on "Manufacture and use of unfermented grape juice"	644	1–16
Hydrocyanic-acid gas, use against household insects, note	626	4
Ice cream, grape, recipe	644	15
Icterus bullocki, feeding habits	630	14
Icterus galbula, feeding habits	630	13
Idaho—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24–30, 32, 34
game laws for 1914	628	16–17, 30, 37, 40, 47
peaches suitable to different sections, time of ripening	633	5
Illinois—		
apple crop, percentage of different varieties	641	17
crops, acreage, yield, production, prices, and value	645	24, 25, 27–35
game laws for 1914	628	17, 30, 37, 41, 47
peaches suitable to different sections, time of ripening	633	5
Indiana—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24, 25, 27–35
game laws for 1914	628	17, 31, 37, 41, 47
peaches suitable to different sections, time of ripening	633	5
Insects injurious to farmer, bird enemies	630	1–27
International Institute of Agriculture—		
crop report for 1914	641	23
report of yields of grain in northern hemisphere	645	8
Iowa—		
apple crop, percentage of different varieties	641	18
farmer—		
living expenses furnished by farm, per family and per capita	635	5
living expenses, purchases per family and per capita	635	6
food consumption by farmer, per family and per capita	635	7, 8
game laws for 1914	628	17, 31, 37, 41, 47
peaches suitable to different sections, time of ripening	633	6
Irish potatoes. *See* Potatoes.		
Irridoprocne bicolor, note	630	8
Irrigation, exercises for agricultural school	638	24
Italy—		
wheat crops, 1912–1914	641	9
wheat production, 1912–1914	629	7
Japan—		
rice production, 1914	641	23
wheat crops, 1912–1914	641	9
Jays, usefulness to farmer, objections, feeding habits	630	19–21
Junco hyemalis, feeding habits	630	10
Kafir corn—		
grain yield, and production, by States	641	32
production, by States	629	24
Kale, growing in home garden, directions, and varieties recommended	647	16–17
Kalmbach, E. R.—		
article on the blue jay	630	19–20
article on the crow	630	17–19

	Farmers' Bulletin No.	Page.
Kansas—		
apple crop, percentage of different varieties	641	18
farmer—		
living expenses furnished by farm, per family and per capita	635	5
living expenses, purchases per family and per capita	635	6
food consumption by farmer, per family and per capita	635	7, 8
game laws for 1914	628	17, 31, 37, 41, 47
peaches suitable to different sections, time of ripening	633	6
Kerosene—		
emulsion, formula, and preparation	650	24–25
sprays for San Jose scale, preparation and application	650	23–26
Kentucky—		
apple crop, percentage of different varieties	641	18
game laws for 1914	628	17, 31, 37, 41, 47
peaches suitable to different sections, time of ripening	633	6
Kingbird, enemy of hawks, note	630	24
Kingbirds, usefulness to farmer, feeding habits	630	23–24
Knots, directions for making various kinds for use in farm work	638	2–5
Kohl-rabi, growing in home garden, directions, and variety recommended	647	17
Labor—		
cost per capita on farm	635	2
farm household, cost, relation to size of family	635	17–18, 20
Laboratory exercises in farm mechanics for agricultural high schools, bulletin by Daniels Scoates	638	1–26
Ladybirds, enemies to San Jose scale	650	11–12
Lambs—		
farm prices on specific dates	629	30
prices paid producers—		
averages for specific dates	641	38
by States	641	34
	645	38
on specific dates	645	43
Laws, game—		
for 1914: A summary of the provisions relating to seasons, export, sale, limits, and licenses	628	1–54
See also Game laws.		
Legislation, game, for 1914, special features, tendency, etc	628	2–13
Lemons, crop conditions on specific dates	629	12
Lettuce, growing in home garden, directions, and varieties recommended	647	17
Leveler, use in peach orchard, description	631	20, 21
Library, agricultural schools, suggestions	638	25
Lima beans, production, by States	629	26
Limes, crop conditions on specific dates	629	12
Lime-sulphur—		
concentrates—		
dilution table	650	20
preparation, handling and storage	650	15–23
self-boiled wash for spraying peach trees, formula	650	22
washes—		
plant for cooking, illustration	650	18, 19
use against San Jose scale, preparation and application	650	15–23
Live stock—		
consumption of feed crops, data for various animals and crops	629	8, 9
farm prices by States	629	28–29
farm prices on specific dates	629	30
prices paid producers—		
averages for specific dates	641	38
by States	641	33–34
	645	38
on specific dates	645	43

	Farmers' Bulletin No.	Page.
Live-stock report for January 1, 1915, time of issuance and scope	645	1
Locust, Rocky Mountain grasshopper, illustrations	637	3, 4
Long Island, game laws for 1914	628	21, 32, 38, 42, 50
Louisiana—		
cotton production, cost per item	641	14
crops, acreage, yield, production, prices and value	645	24, 28, 33–36
field crops imported, quantity and value of four products	645	13
game laws for 1914	628	5, 18, 31, 37, 41, 47
peaches suitable, time of ripening	633	6
sugar and cane yields, forecasts	645	10
Machinery—		
farm, exercises for agricultural school	638	14–19
grape juice manufacture, description	644	9, 10, 11, 12, 13
Maine—		
apple crop, percentage of different varieties	641	17
crops, acreage, yield, production, prices, and value	645	24, 26, 27, 28, 31, 32, 34
game laws for 1914	628	18, 31, 37, 41, 48
Malenerpes erythrocephalus, feeding habits	630	26–27
Manitoba—		
game laws for 1914	628	26, 34, 39, 43, 53
game laws passed in 1914	628	7
Marketing cotton—		
cooperative	641	14–16
discussion	641	14–16
Markets, cotton, foreign countries, shipments, etc	641	12
MARLATT, C. L., bulletin on "The house centipede"	627	1–4
Martin, feeding and nesting habits	630	8, 9
Maryland—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24, 25, 27–34
game laws for 1914	628	18, 31, 37, 41, 48
game laws passed in 1914	628	5
peaches suitable to different sections, time of ripening	633	6
Massachusetts—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24, 28, 30, 31, 32, 34, 35
game laws for 1914	628	18, 31, 37, 41, 48
game laws passed in 1914	628	5–6
peaches suitable to different sections, time of ripening	633	6
Mayetiola destructor. *See* Hessian fly.		
McAtee, W. L., article on the nighthawk	630	24–25

	Farmers' Bulletin No.	Page.
McLain, J. H., bulletin on "Eradication of the cattle tick necessary for profitable dairying"	639	1–4
Meadowlarks, usefulness to farmer, feeding habits	630	14–15
Meal, cottonseed. *See* Cottonseed meal.		
Meat—		
consumption per capita by farmers, amounts raised and bought, 10 States	635	11, 12
consumption per capita on farm	635	2
Meat animals—		
prices, trend	645	12
See also Live stock.		
Mediterranean countries, citrus fruit prospects, 1914–1915	629	12–14
Melanoplus atlanis, destruction by poison bait, instance	637	10
Melanoplus bivittatus, description, distribution, life history and habits	637	3–4
Melanoplus differentialis, description, distribution, life, history, and habits	637	2, 3–4
Melanoplus spretus, illustration	637	3
Melons, growing in home garden, directions and varieties recommended	647	17–18
Melospiza melodia, feeding habits	630	9–10
Merisus destructor, enemy of Hessian fly, note	640	16
Michigan—		
apple crop, percentage of different varieties	641	17
crops, acreage, yield, production, prices, and value	645	24, 25, 27–32, 34
game laws for 1914	628	19, 31, 37, 41, 48
peaches suitable to different sections, time of ripening	633	7
Milk—		
consumption per capita by farmers, 10 States	635	11
production of cows, effect of tick infestation	639	1–2
production of cows, effects of dipping and spraying for tick destruction	639	2
Millet, yield and production by States	629	24
Minnesota—		
crops, acreage, yield, production, prices and value	645	24–32, 34
game laws for 1914	628	19, 32, 37, 41, 48
Mississippi—		
field crops imported, quantity and value of four products	645	13
game laws for 1914	628	19, 32, 38, 42, 48
game laws passed in 1914	628	6
Missouri—		
apple crop, percentage of different varieties	641	17
game laws for 1914	628	19, 32, 38, 42, 49
peaches suitable to different sections, time of ripening	633	7
Mold fungi, resistance to heat, note	644	3
Montana—		
crops, acreage, yield, production, prices and value	645	24–30, 32, 34, 35
game laws for 1914	628	19, 32, 38, 42, 49
Mulching blackberries, advantages	643	8
Murray, Nat C.—		
article on "Disposition of feed crops"	629	8–9
article on "The cost of producing cotton"	641	12–14

	Farmers' Bulletin No.	Page.
Murray, Nat C.—Continued.		
article on "The wheat crop of 1913–1914"	629	4–5
estimates on agricultural products shipped into cotton States	645	12–13
statement on "Food production and requirements of various countries"	641	20–22
statements and statistics on "The purchasing power of farmers"	645	19–23
Muscadine grapes, value for grape juice, quality of products	644	4
Museums, carpet-beetle pest, note	626	3
Muskmelons, growing in home garden, directions and varieties recommended	647	17–18
Must—		
grape, analysis of product of concord and California vinifera varieties	644	2
grape, use of term	644	1
See also Grape juice.		
Mustard, growing in home garden, directions and varieties recommended	647	18
Nebraska—		
apple crop, percentage of different varieties	641	18
game laws for 1914	628	19–20, 32, 38, 42, 49
peaches suitable to different sections, time of ripening	633	7
Netherlands, wheat crops, 1912–1914	641	9
Nevada ,crops, acreage, yield, production, prices and value	645	24–29, 32, 34
New Brunswick, game laws for 1914	628	27, 34, 39, 43, 53
New Hampshire—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24, 28, 29, 31, 32, 34, 35
game laws for 1914	628	20, 32, 38, 42, 50
peaches suitable to different sections, time of ripening	633	7
New Jersey—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24, 25, 27, 28, 30–34
game laws for 1914	628	20, 32, 42, 50
game laws passed in 1914	628	6
peaches suitable to different sections, time of ripening	633	7
New Mexico—		
crops, acreage, yield, production, prices, and value	645	24–29, 32, 34
game laws for 1914	628	20, 32, 38, 42, 50
peaches suitable to different sections, time of ripening	633	7–8
New York—		
apple crop, percentage of different varieties	641	17
coal and wood used per farm family, practices, remarks	635	16
crops, acreage, yield, production, prices, and value	645	24, 25, 27–32, 34, 35
farmer, living expenses furnished by farm, per family and per capita	635	5
farmer, living expenses, purchases per family, and per capita	635	6
food consumption by farmer, per family, and per capita	635	7, 8
game laws for 1914	628	21, 32, 38, 42, 50

	Farmers' Bulletin No.	Page.
New York—Continued.		
game laws passed in 1914	628	6
peaches suitable to different sections, time of ripening	633	8
Newfoundland, game laws for 1914	628	27, 34, 39, 43, 53
Nighthawk, usefulness to farmer, feeding habits	630	24–25
North Carolina—		
apple crop, percentage of different varieties	641	18
cotton production, cost per item	641	14
crops, acreage, yield, production, prices, and value	645	24, 25, 27, 28, 30–35
farmer, living expenses furnished by farm, per family, and per capita	635	5
farmer, living expenses, purchases per family, and per capita	635	6
field crops imported, quantity, and value of four products	645	13
food consumption by farmer, per family, and per capita	635	7, 8
game laws for 1914	628	21, 32, 38, 42, 50
peaches suitable, time of ripening	633	8
North Dakota—		
game laws for 1914	628	21, 32, 38, 42, 50
game preserve at Sullys Hill National Park, appropriation	628	5
Northwest Territories, game laws for 1914	628	28
Nova Scotia, game laws for 1914	628	27, 34, 39, 43, 54
Nursery, peach, site	631	8
Nuts—		
prices paid producers, averages for specific dates	641	38
prices paid producers, by States	641 645	37 39
See also under name of specific product.		
Oats—		
acreage, production, and farm value	645	4
acreage, yield, production, and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	28
farm prices on specific dates	645	23
prices paid producers, by States	641	33
prices paid producers on specific dates	641 645	38 43
prices, range at market centers	629 641 645	30 39 44
production in leading five States	645	5
shipped into cotton States, quantity and value, by States	645	13
weight to measured bushel, by States	641	29
yield, production, and prices, 1913, 1914	629	3
yield, production, quality, and price, by States	629	21
yield, production, quality, and prices	641	2
Ohio—		
apple crop, percentage of different varieties	641	17
crops, acreage, yield, production, prices, and value	645	24, 25, 27–35
farmer, living expenses furnished by farm, per family, and per capita	635	5
farmer, living expenses, purchases per family, and per capita	635	6
food consumption by farmer, per family, and per capita	635	7, 8
game laws for 1914	628	21, 32, 38, 42, 50
game laws passed in 1914	628	6
peaches suitable to different sections, time of ripening	633	8

	Farmers' Bulletin No.	Page.
Oklahoma—		
apple crop, percentage of different varieties	641	18
cotton production, cost per item	641	14
crops, acreage, yield, production, prices, and value	645	24, 25, 27–30, 32–34, 36
field crops imported, quantity, and value of four products	645	13
game laws for 1914		22, 32, 38, 42, 50
peaches suitable, time of ripening	633	8
Okra, growing in home garden, directions and varieties recommended	647	18
Olives, crop conditions on specific dates	629	12
Onderdonk, Gilbert, classification of peaches	633	11–13
Onions—		
acreage, yield, and production, by States, of surplus production	645	10
farm prices on specific dates	629	30
growing in home garden, directions and varieties recommended	647	18–19
prices paid producers, by States	641	35
	646	40
prices paid producers on specific dates	641	38
	645	43
production and prices by States	629	26
Ontario—		
game laws for 1914	628	27, 34, 39, 43, 54
game laws passed in 1914	628	7
Oranges, crop conditions in Florida and California on specific dates	629	12
	641	6
	649	10
Orchard, peach—		
interplanted crops, choice and management	632	18–19
tillage, advantages, suggestions, and practices	631	17–21
See also Peach orchard.		
Orchards—		
cover crops, quantity of seed per acre, management	631	21–23
root-knot control	648	14–15
Oregon—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24–30, 32, 34
game laws for 1914		22, 32, 38, 42, 50
peaches suitable to different sections, time of ripening	633	8
Orioles, usefulness to farmers, feeding and nesting habits	630	13–14
Oyster plant, growing in home garden, directions and varieties recommended	647	23–24
Pacific coast jays, feeding habits, damage to orchard fruits	630	20–21
PALMER, T. S., W. F. BANCROFT, and FRANK L. EARNSHAW, bulletin on "Game laws for 1914: A summary of the provisions relating to seasons, export, sale, limits, and licenses"	628	1–54
Parsley, growing in home garden, directions and varieties recommended	647	19
Parsnips—		
growing in home garden, directions and varieties recommended	647	19–20
preparation for table, note	647	20
Passer domesticus, notes	630	10, 11
Pasteurization, grape juice, heat requirements, note	644	3, 4
Pasteurizer, grape juice, description	644	11
Pasture, treating with poison bait for grasshoppers, safety to cattle, instance	637	10

	Farmers' Bulletin No.	Page.
Peach—		
Chinese cling group, varieties, value and distribution	633	13
growing—		
antiquity and introduction into America	631	1–2
distribution and statistics by States	631	2–3
Missouri experiment station, managment of trees to prevent freezing	632	21–22
soil requirements	631	3
temperature, considerations	631	3
thinning fruit, managment and advantages	632	14–16
"Honey group," varieties and region suitable	633	12
orchard—		
control of insect pests and fungous diseases, suggestions	632	16–17
establishment, selection and planting of trees, etc	631	4–17
location and site, considerations	631	4–7
orchards—		
elevation and slope, considerations	631	5–7
soil fertility, maintenance	631	21–24
use of fertilizers	631	23–24
peen-to race, introduction, varieties, region suitable	633	12
Persian race, introduction, varieties and distribution	633	13
seeds, planting, practices	631	9
South-China race—		
varieties and region suitable	633	12
varieties, growth habits, etc	633	13
Spanish race, varieties and region suitable	633	12
trees—		
injury by San Jose scale, treatment	650	2
injury from San Jose scale, appearance and damage	650	1–2, 4
interplanting in apple orchard, remarks	632	19
nursery stock, requirements	631	10–12
propagation	631	8–9
protection from cold and heat, practices	632	20–21
pruning, methods and results	632	1–9
renewal of tops, managment	632	10–13
selection, planting, preparation of land, etc	631	10–17
spraying for San Jose scale, washes, etc	650	22–23
susceptibility to freezes, causes	632	20–22
top working	632	12–13
varieties, selection for planting, considerations	633	1–3
Peaches—		
classification, "Onderdonk system"	633	11–13
consumption per capita by farmers, 10 States	635	11
farm prices on specific dates	629	30
growing—		
pruning, renewal of tops, thinning, interplanted crops, and special practices, bulletin by H. P. Gould	632	1–23
sites, propagation, planting, and maintenance of soil fertility, bulletin by H. P. Gould	631	1–24
varieties and classification, bulletin by H. P. Gould	633	1–13
hardiest varieties in wood and in bud	633	8
prices paid producers—		
averages for specific dates	641	38
by States	641	35
ripening order, of different varieties in various States	633	3–10
tender varieties	633	8
varieties for various States, order of ripening, etc	633	3–11
Peanuts—		
crop condition on specific dates, by States	629	27
farm prices on specific dates	629	30
prices paid producers—		
average for specific dates	641	38
by States	645	39
on specific dates	645	43
yield, production, quality, and prices, by States	641	32

	Farmers' Bulletin No.	Page.
Pears—		
crop conditions on specific dates	629	12, 25
farm prices on specific dates	629	30
prices paid producers—		
averages for specific dates	641	38
by States	641	35
	645	39
on specific dates	645	43
production and quality, by States	641	30
Peas—		
Canadian, crop condition on specific dates, by States	629	24
growing in home garden, directions and varieties recommended	647	20
Pecans, prices paid producers—		
averages for specific dates	641	38
by States	641	37
	645	39
on specific dates	645	43
Pennsylvania—		
apple crop, percentage of different varieties	641	17
crops, acreage, yield, production, prices, and value	645	24, 25, 27–35
farmer—		
living expenses furnished by farm, per family and per capita	635	5
living expenses, purchases per family and per capita	635	6
food consumption by farmer, per family and per capita	635	7, 8
game laws for 1914	628	22, 33, 38, 42, 51
peaches suitable to different sections, time of ripening	633	9
Peppers, growing in home garden, directions and varieties recommended	647	21
Petrochelidon lunifrons, feeding and nesting habits	630	8
Petroleum—		
crude, washes for San Jose scale, preparation	650	23–26
sprays for San Jose scale, preparation and application	650	23–26
Phœbe, usefulness to farmer, feeding and nesting habits	630	21–23
Pipilo Eruthrophalmus, feeding and nesting habits	630	9
Planesticus migratorius, spp., feeding habits, usefulness, etc	630	3–4
Planting table for gardeners	647	28
Plants, root-knot disease, appearance, effect, etc	648	1–4
Platygaster herrickii, enemy of Hessian fly, note	640	16
Poison baits for grasshoppers, formulas and use	637	9–10
Polygnotus hiemalis, enemy of Hessian fly, description and value	640	14–15
Polygnotus minutus, enemy of Hessian fly, note	640	15
Pop corn—		
prices paid producers, by States	645	40
prices paid producers on specific dates	645	43
Pork, consumption per capita on farm	635	2
Portugal, citrus fruit prospects, 1914–1915	629	13
Potatoes—		
acreage, 1914	629	2
acreage, production and farm value	645	4
acreage, yield, production and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	32
consumption per capita by farmers, 10 States	635	11
crop condition—		
and prices on specific dates, by States	629	22
on specific dates, comparisons	629	2
farm prices on specific dates	645	23
growing in home garden, directions and varieties recommended	647	21–23
prices paid producers—		
averages for specific dates	641	38
on specific dates	645	43
production in leading five States	645	5
root-knot disease, effect	648	4
sweet. *See* Sweet potatoes.		
yield, production, and prices, 1913, 1914	629	3
yield production, quality and prices	641	2, 26

	Farmers' Bulletin No.	Page.
Poultry—		
and eggs, consumption per capita on farm	635	2
consumption—		
of various feed crops per annum	629	8
per capita by farmers, 10 States	635	11, 12
prices paid producers, by States	645	42
prices paid producers on specific dates	645	43
Prairie hay—		
prices paid producers, by States	641 645	36 41
prices paid producers on specific dates	645	43
President, proclamation for protection of migratory birds, text	628	9–13
Prices—		
agricultural products, range at market centers	645	44
apples, on 15th of each month, 1910–1914	645	10
crops, 1913, 1914	641	2
farm products—		
by States	645	38–42
on specific dates, by States	629	28–29
trend	641 645	7 12
field crops, on specific dates	645	23
paid to producers of farm products, by States	641	33–38
Prince Edward Island, game laws for 1914	628	27, 34, 43, 54
Progne subis, note	630	8
Prune orchards, depredations by jays, instances	630	20
Prunes, crop conditions on specific dates	629	12
Pruning tomatoes, directions	642	7
Prussia—		
grain crops, 1914	641	23
wheat crops, 1912–1914	641	9
Punch, grape, recipe	644	15
QUAINTANCE, A. L., bulletin on "The San Jose scale and its control"	650	1–27
Quebec, game laws for 1914	628	28, 34, 39, 43, 54
Quiscalus quiscula, feeding habits	630	12
Radishes, growing in home garden, directions and varieties recommended	647	23
Recipes, grape juice	644	15–16
Red-headed woodpecker, feeding habits	630	26
Red-winged blackbirds, usefulness to farmer, feeding habits	630	15–17
Reed bird, usefulness to farmer, feeding habits	630	17
Rent, house, per capita on farm	635	2
Rhode Island—		
crops, acreage, yield, production, prices, and value	645	24, 28, 32, 34
game laws for 1914	628	23, 33, 38, 42, 51
game laws passed in 1914	628	6
peaches suitable, time of ripening	633	9
Rhubarb, growing in home garden	647	23
Rice—		
acreage, 1914	629	2
acreage, production and farm value	645	4
acreage, yield, production, and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	36
bird, usefulness to farmer, feeding habits	630	17
crop condition on specific dates, by States	629	23
crop condition on specific dates, comparisons	629	2
farm prices on specific dates	645	23
production in leading five States	645	5
production of Spain and Japan, 1914	641	23
yield, production, and prices, 1913, 1914	629	3

	Farmers' Bulletin No.	Page.
Riparia riparia, note	630	8
Robins, usefulness to farmer, feeding habits, varieties	630	3–4
Root nodules, nitrogen-fixing bacteria, description and illustration	648	2
Root-gall. *See* Root-knot.		
Root-knot—		
cause	648	4
control, bulletin by Ernest A. Bessey and L. P. Byars	648	1–19
control methods	148	12–17
description and illustration	648	2–3
effect on plants	648	1–4
plants attacked, list	648	8–9
prevalence	648	1
resistant crops, selection	648	17–18
spread, methods, and conditions favorable	648	10–12
Rope halter, directions for making	638	5
Ropework exercises for agricultural high schools	638	1–6
Rotary-brush stripper, crimson-clover seed harvesting, description and operation	646	7–8
Roumania, wheat crops, 1912–1914	841	9
Russia—		
Asiatic, grain crops, 1914	641	23
food production and requirements	641	21
foodstuffs, production, imports and exports, items	641	22
wheat crops, 1912–1914	841	9
wheat production, 1912–1914	629	7
Rutabagas, growing in home garden, direction and variety recommended	647	26
Rye—		
acreage and condition on specific dates	645	37
acreage, production and farm value	645	4
acreage, yield, production and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	30
fall sowings and condition	645	8
farm prices on specific dates	645	23
prices, by States	629	29
prices paid producers, by States	641	33
prices paid producers on specific dates	641 645	38 43
prices, range at Chicago	641 645	39 44
production in leading five States	645	5
yield, production, and prices, 1913, 1914	629	3
yield, production, quality, and prices	641	2
Salsify, growing in home garden, directions and variety recommended	647	23–24
San Jose scale—		
and its control, bulletin by A. L. Quaintance	650	1–27
control measures	650	14–27
description and spread	650	7–8
description, history, and habits	650	3–7
enemies	650	11–13
food plants, list	650	9–11
injury to plants and fruit, character and extent	650	1–3
lime-sulphur washes for summer spraying	650	20–23
Sarcophaga—		
georgina, enemy of grasshopper, description	637	5
kellyi, enemy to grasshopper	637	5
spp., destruction of grasshoppers	637	4–6
Saskatchewan—		
game laws for 1914	628	28, 34, 39, 43, 54
game laws passed in 1914	628	7
Say phœbe, feeding habits	630	23

	Farmers' Bulletin No.	Page.
Sayornis—		
nigricans, feeding habits	630	22–23
phoebe, feeding habits	630	21–23
sayus, feeding habits	630	23–24
Schools, agricultural high, laboratory exercises in farm mechanics, bulletin by Daniels Scoates	638	1–26
SCOATES, DANIELS, bulletin on "Laboratory exercises in farm mechanics for agricultural high schools"	638	1–26
Scutigera forceps. *See* House centipede.		
Seed—		
crimson clover—		
commercial growing	646	8–11
harvesting devices, descriptions and operations	646	2–8
production, bulletin by J. M. Westgate	646	1–13
shattering in field, preventive measures	646	8
sowing in hull, practices	646	2, 8
yields	646	11
farm, prices paid producers, by States	645	41
use of various feed crops per annum	629	8
See also under name of specific product.		
Seeds—		
farm—		
prices paid by farmers, by States	645	42
prices paid by farmers on specific dates	645	43
garden, planting for early crops	647	8
Sheep—		
consumption of various feed crops per annum	629	8
farm prices on specific dates	629	30
prices by States	629	28
prices paid producers, by States	641 645	34 38
prices paid producers on specific dates	641 645	38 43
Sherbet, grape, recipe	644	15
Sialia—		
currucoides, feeding habits	630	3
sailis, feeding habits	630	2–3
Sirup, consumption by farmer, investigations	635	10
Skein centipede. *See* House centipede.		
Skunk, enemy of grasshopper	637	4
Sled, device for removing orchard brush	632	9
Snowbird, feeding habits	630	10
Soap washes, preparation for use against San Jose scale	650	26–27
Soil—		
erosion, crimson clover as preventive	646	1
fertility, maintenance in peach orchards	631	21–24
garden, preparation and treatment	647	5–8
Soldering, directions	638	9–10
Song sparrow, feeding habits	630	9–10
Sorghum—		
crop condition on specific dates, by States	629	27
yield per acre, by States	641	31
South—		
home garden, bulletin by H. C. Thompson	647	1–28
tomato growing, bulletin by H. C. Thompson	642	1–13
South Carolina—		
cotton production, cost per item	641	14
crops, acreage, yield, production, prices, and value	645	24, 25, 27, 28, 30, 32–36
field crops imported, quantity and value of four products	645	13
game laws for 1914	628	23, 33, 38, 42, 51
game laws passed in 1914	628	6
peaches suitable to different sections, time of ripening	633	9

	Farmers' Bulletin No.	Page.
South Dakota, game laws for 1914	628	23, 33, 38, 42, 51
Soy beans—		
prices paid producers, by States	641	36
	645	41
prices paid producers on specific dates	641	18
	645	43
Spain—		
citrus fruit prospects, 1914–1915	629	12–13
grain crops, 1914	641	23
wheat production, 1912–1914	629	7
	641	9
wine production, 1914	641	23
Sparrow, song, feeding habits	630	9–10
Sparrows, usefulness to farmer, feeding habits, etc	630	9–11
Sphaerostilbe coccophila, enemy of San Jose scale	650	13
Spinach, growing in home garden, directions and variety recommended	647	24
Spizella—		
monticola, feeding habits	630	10
passerina, feeding habits	638	9–10
pusilla, feeding habits	630	9–10
Split-log drag, construction, directions	638	24–25
Sporotrichum globulferum, destruction of grasshoppers	637	5, 7
Spraying—		
apparatus, illustrations and descriptions	650	24, 25, 26, 27
summer, for San Jose scale, washes, etc	650	20–23
tomatoes, directions	642	10
Sprays—		
kerosene, for San Jose scale, preparation and application	650	23–26
lime-sulphur, use against San Jose scale, results of different kinds	650	22
use against San Jose scale, preparation, etc	650	14–27
Spring wheat. *See* Wheat, spring.		
Squash—		
growing in home garden, directions and varieties recommended	647	24–25
preparation for table, directions	647	24
Stelgidopteryx serripennis, note	630	8
Steller jay, feeding habits, damage to orchard fruits	630	20–21
Sterilization, bottles for grape juice, heat requirements, note	644	3
Strippers, harvesting crimson-clover seed, devices and operation	646	2–8
Stubenrauch, J. W., originator of peach varieties, note	633	10
Sturnella—		
magna, feeding habits	630	14–15
neglecta, feeding habits	630	14–15
Sugar—		
beet, production, 1914, estimate	641	4–5
beets. *See* Beets, sugar.		
cane. *See* Cane, sugar.		
consumption per capita by farmers, 10 States	635	11
yields in Louisiana, forecast	645	10
Sugar-beet forecast for 1915	629	11
Sulphur—		
compounds, powdered, for sprays, note	650	23
dioxid and trioxid, use against household insects, note	626	4
Surveying, exercises for agricultural school	638	19–21
Swallow—		
barn, feeding and nesting habits	630	8, 9
cliff, feeding and nesting habits	630	8, 9
northern violet-green, note	630	8
rough-winged, note	630	8
white-bellied, feeding and nesting habits	630	8
Swallows, usefulness to farmer, feeding and nesting habits	630	8–9
Sweet potatoes—		
acreage, 1914	629	2
acreage, yield, production, and value, 1899–1914	645	4, 22

	Farmers' Bulletin No.	Page.
Sweet potatoes—Continued.		
acreage, yield, production, prices, and value, by States	645	33
consumption per capita by farmers, 10 States	635	11
crop condition and prices on specific dates, by States	629	22
crop condition on specific dates, comparisons	629	2
farm prices on specific dates	629	30
	645	23
growing in home garden, directions and varieties recommended	647	22–23
harvesting, curing, and storing	647	22–23
prices paid producers on specific dates	641	38
	645	43
production in leading five States	645	5
yield, production, and prices, 1913, 1914	629	3
	641	2
yield, production, quality, and prices, by States	641	27
Swine—		
consumption of feed crops, per annum	629	8
See also Hogs.		
Switzerland, wheat crops, 1912–1914	641	9
Syllabub, recipe	644	16
Tachycineta thalassina, note	630	8
Tea, consumption per capita by farmers, 10 States	635	11
Tennessee—		
apple crop, percentage of different varieties	641	18
cotton production, cost per item	641	14
field crops imported, quantity and value of four products	645	13
game laws for 1914	628	23, 33, 38, 42, 51
peaches suitable to different sections, time of ripening	633	9
Terracing, exercises for agricultural school	638	23–24
Texas—		
cotton production, cost per item	641	14
crops, acreage, yield, production, prices, and value	645	24, 25, 27–30, 32–36
farmer, living expenses—		
furnished by farm, per family and per capita	635	5
purchases per family and per capita	635	6
field crops imported, quantity and value of four products	645	13
food consumption by farmer, per family and per capita	635	7, 8
game laws for 1914	628	23–24, 33, 38, 42, 52
peaches suitable to different sections, time of ripening	633	9–10
Thompson, H. C.—		
bulletin on "The home garden in the South"	647	1–28
bulletin on "Tomato growing in the South"	642	1–13
"Thousand legs." *See* House centipede.		
Thrasher, brown, usefulness to farmer, feeding and nesting habits	630	7
Thrashing crimson clover with flail	646	2
Tick, cattle—		
cost of feeding, experiments	639	3–4
effect on milk production and body weight	639	1–2
eradication necessary for profitable dairying, bulletin by J. H. McLain	639	1–4
Timber, preservation by woodpeckers	630	25
Timothy—		
hay—		
prices paid producers, averages for specific dates	641	38
prices paid producers, by States	641	36
	645	41
prices paid producers on specific dates	645	43
seed—		
prices paid by farmers	641	38
prices paid by farmers, by States	641	37
	645	42

	Farmers' Bulletin No.	Page.
Timothy—Continued.		
seed—Continued.		
prices paid by farmers on specific dates	629	30
prices paid producers, by States	641	36
	645	41
Tit—		
bush, feeding habits	630	5–6
tufted, feeding habits	630	5
Titmice, usefulness to farmer, feeding habits, etc	630	4–5
Tobacco—		
acreage, production, and farm value	645	4
acreage, yield, production, and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	35
crop condition on specific dates, by States	629	23
farm prices on specific dates	645	23
production in leading five States	645	5
yield—		
production and prices, 1913, 1914	629	3
production and quality	641	2
production and quality, by States	641	29
Tomato plants, growing and transplanting	642	1–5, 6–7
Tomatoes—		
cost of growing for cannery and for market, items	642	11–12
crop condition on specific dates, comparisons	629	2
cultivation	642	7
farm prices on specific dates	629	30
growing—		
in home garden, directions and varieties recommended	647	25
in the South, bulletin by H. C. Thompson	642	1–13
rotation of crops, need and suggestions	642	8
harvesting, directions	642	10–11
prices paid producers, averages for specified dates	641	38
prices paid producers, by States	641	35
production and prices, by States	629	26
pruning and staking	642	7–8
soil requirements, and preparation	642	5–6
treatment for prevention of diseases	642	9–10
varieties, value for various uses	642	11
Tools, farm, prices and comparisons, 1899–1913	645	19–20
Towhee, usefulness to farmer, feeding and nesting habits	630	9
Tozostoma rufum, usefulness to farmer, feeding and nesting habits	630	7
Transplanting garden plants, directions	647	9
Tree—		
swallow, feeding and nesting habits	630	8
sparrow, feeding habits	630	10
Troglodytes aedon, feeding and nesting habits	630	6
Turkey, citrus fruit prospects, 1914–1915	629	13
Turkeys—		
prices paid producers, averages for specific dates	641	38
prices paid producers, by States	641	34
	645	42
prices paid producers on specific dates	645	43
Turnips—		
growing in home garden, directions and varieties recommended	647	25–26
prices paid producers, by States	645	40
prices paid producers on specific dates	645	43
Tyrannus—		
tyrannus, feeding habits	630	23–24
verticalis, feeding habits	630	24
vociferans, feeding habits	630	24
United Kingdom, foodstuffs, production, imports and exports, items	641	22
URBAHNS, THEODORE D., bulletin on "The chalcis-fly in alfalfa seed"	636	1–10
Utah—		
crops, acreage, yield, production, prices, and value	645	24–30, 32, 34

Utah—Continued.	Farmers' Bulletin No.	Page.
game laws for 1914	628	24, 33, 38, 42, 52
peaches suitable to different sections, time of ripening	633	10
Vegetables—		
consumption on farm, remarks	635	13
cultivation in home garden	647	10
farm prices on specific dates	629	30
planting table	647	28
prices paid producers, averages for specific dates	641	38
prices paid producers, by States	641	35
	645	40
subject to root-knot	648	8–9
succession and rotation of crops in home garden	647	5–6
yield, production, and prices of various kinds, by States	629	26
Velvet beans, crop conditions on specific dates	629	12
Vermont—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24, 26, 27, 28, 29, 31, 32, 34, 35
farmer, living expenses furnished by farm, per family, and per capita	635	5
farmer, living expenses, purchases per family and per capita	635	6, 7
food consumption by farmer, per family and per capita	635	7, 8
game laws for 1914	628	24, 33, 38, 42, 52
peaches, suitable, time of ripening	633	10
Virginia—		
apple crop, percentage of different varieties	641	17
crops, acreage, yield, production, prices, and value	645	24, 25, 27–36
field crops imported, quantity and value of four products	645	13
game laws for 1914	628	24, 33, 38, 42, 52
game laws passed in 1914	628	6
peaches, suitable to different sections, time of ripening	633	10
Wagon for burning brush from peach orchards, description	632	9
Walnuts—		
black, prices paid producers, averages for specific dates	641	38
crop, conditions on specific dates	629	12
prices paid producers, by States	641	37
	645	39
prices paid producers on specific dates	645	43
Washington—		
apple crop, percentage of different varieties	641	17
crops, acreage, yield, production, prices and value	645	24–30, 32, 34
game laws for 1914	628	24–25, 33, 39, 42, 52
peaches suitable to different sections, time of ripening	633	10
Water supply, farm dwellings, remarks	635	17
Weather conditions—		
in corn and wheat regions, diagrams	629	34–35
in cotton regions, diagram	629	32
WEBSTER, F. M.—		
bulletin on "Alfalfa attacked by the clover-root curculio"	649	1–8
bulletin on "The grasshopper problem and alfalfa culture"	637	1–10
bulletin on "The Hessian fly"	640	1–20

	Farmers' Bulletin No.	Page.
Weed seed—		
destruction by sparrows, estimate	630	10
occurrence in crimson-clover seed, descriptions	646	12
Weeds troublesome in crimson clover fields	646	12
West Virginia—		
apple crop, percentage of different varieties	641	17
crops, acreage, yield, production, prices, and value	645	24, 25, 27, 28, 30–35
game laws for 1914	628	25, 33, 39, 42, 52
peaches suitable, time of ripening	633	10
WESTGATE, J. M., bulletin on "Crimson clover: Seed production"	646	1–13
Wheat—		
acreage and condition on specific dates	645	37
acreage, production, and farm value	645	4
acreage, yield, production, and value, 1899–1914	645	22
acreage, yield, production, prices, and value, by States	645	25–27
Argentina, acreage, production and exports, 1892–1915, yearly	645	17
crop—		
1913–1914, article by Nat C. Murray	629	4–5
outlook in European countries	641	8–9
Southern Hemisphere, statistics	645	15–17
world, 1914, article by Charles M. Daugherty	629	6
world, outlook	641	7–9
crops, 1912–1914, by countries	641	9
durum, immunity from Hessian fly	640	11
fall sowing to avoid Hessian fly, dates for different sections	640	16–18
fall sowings and conditions	645	7–8
farm prices on specific dates	645	23
freight rates, New York to Liverpool	645	7
Hessian-fly damage, nature	640	3–4
movement, 1913–1914, monthly	629	5
plant, effect of Hessian-fly larvæ	640	9–10
prices—		
on specific dates, by States	629	19
paid producers, averages for specific dates	641	38
paid producers, by States	641	33
paid producers on specific dates	645	43
range at market centers	629	30
	645	44
production—		
1912–1914	629	6
food and seed requirements and surplus or deficiency, by States	629	18
in leading five States	645	5
in United States, Canada, India, etc., 1912–1914	629	6
purchasing power of 1 acre, 1899–1913	645	21
regions, weather conditions, diagrams	629	34–35
shipped into cotton States, quantity and value, by States	645	13
spring—		
acreage, production, and farm value	645	4
acreage, yield, production, prices, and value, by States	645	26
production in leading five States	645	5
yield, production, and prices, 1913–1914	629	3
yield, production, quantity, and price, by States	629	20
stuble, burning for control of Hessian fly	640	18–19
supplies and requirements, article by Nat C. Murray	629	5–6
varieties immune to Hessian fly	640	11
volunteer, destruction for control of Hessian fly	640	19
weight to measured bushel, by States	641	29
yield, production and prices, 1913–14	629	3
yield, production, quality, and prices	641	2
Wheel hoe, illustration	647	11
White potatoes. *See* Potatoes.		

	Farmers' Bulletin No.	Page.
White-crowned sparrow, note	630	10
White-throated sparrow, note	630	10
Widdermuth, V. L., statements on clover-root curculio	649	2, 3, 4–5
Wine, production in Spain, 1914	641	23
Wines, ancient, historical notes	644	1–2
Winter wheat. *See* Wheat.		
Wisconsin—		
apple crop, percentage of different varieties	641	18
crops, acreage, yield, production, prices, and value	645	24–32, 34, 35
farmer—		
living expenses furnished by farm, per family, and per capita	635	5
living expenses, purchases per family, and per capita	635	6
food consumption by farmer, per family, and per capita	635	7, 8
game laws for 1914	628	25–26, 33, 39, 42, 52
Wood and coal, consumption per capita on farm	635	2
Wood, consumption per farm family and per capita, amount bought, ten States	635	15–16
Woodpeckers, usefulness to farmer, feeding habits	630	25–27
Wool—		
farm prices on specific dates	629	30
prices—		
paid producers, averages for specific dates	631	38
paid producers, by States	645	38
paid producers on specific dates	645	43
range at market centers	641	39
	645	44
Wren, house, feeding and nesting habits	630	6
Wrens, usefulness to farmer, feeding habits	630	6–7
Wyoming—		
crops, acreage, yield, production, prices, and value	645	24–30, 32, 34
game laws for 1914	628	26, 33, 39, 42, 52
Yellow-billed cuckoo, feeding habits	630	27
Yukon, game laws for 1914	628	28, 34, 39, 43, 54

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Perkins